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Vol. X

THE RICE WORM (*TYLENCHUS ANGUSTUS*) AND ITS CONTROL.

BY

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The area affected and the extent of the damage.

In a previous publication[1] an account was given of a new and exceedingly serious disease of rice, called locally " ufra," in the great rice-growing deltaic tract at the head of the Bay of Bengal.

This tract comprises one of the main rice areas of India. The districts actually known to be affected (Noakhali, Tippera, Dacca, Faridpur, and Backergunge) contained, in 1916, nearly 6 million acres out of the 21 million acres under this cereal in Bengal. Adjoining them are other districts so similar in climatic conditions and agricultural practices that they are liable to infection and indeed are likely to be, in some cases, already infected. This threatened area adds another 6 million acres of rice in Bengal and over 2 million acres in Sylhet. In all of this vast extent rice occupies over 70 per cent. of the cultivated land ; hardly any alternative food crop is grown, and the great bulk of the tract is totally unsuited to any other. Hence it is probable that no plant disease hitherto observed in India, except the cereal rusts that periodically take heavy toll of the wheat crop in Northern and Central India, possesses such potentialities for harm as ufra. The intensity of the attack no less than the importance of the crop affected warrants this view.

In most of the districts referred to, communications are defective and agricultural intelligence is backward. While the paddy is growing, the fields

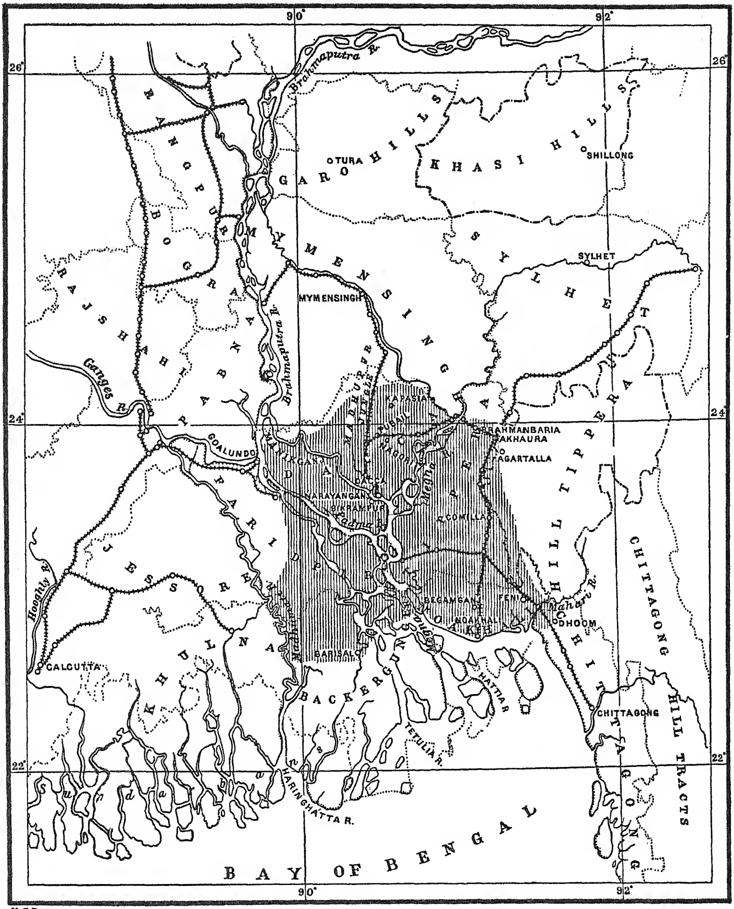
[1] Butler, E. J. " Diseases of Rice." *Agric. Res. Inst., Pusa, Bul.* 34, 1913.

are submerged with flood water from a few inches to 12 feet or more* in depth. Traffic is confined to boats, except along a few high-roads. The water falls after the rains, and at the time when the disease is at its height even boat traffic becomes difficult outside the main waterways. Ufra may remain undetected unless the fields are actually visited, and this is not always as easy as it appears. Where, as is often the case, the disease is not recognized as such but attributed to thunder or other uncontrollable agencies, outside assistance is not invoked. The cultivator considers himself unfortunate, but it does not occur to him to report his misfortune to the authorities. The agricultural staff, ridiculously small for the area, may be long before it learns that anything is wrong. Thus there are large tracts in Faridpur and Backergunge where much damage has been done for the past 10 years but which were only discovered in 1916. When boat traffic is easy, ufra is in its earliest stage in the winter crop and hard to detect; when, on the other hand, the ground is dry enough for walking, the harvest is over. In certain places it has been noticeable that the reports of damage observed by the staff employed in surveying the infected districts are chiefly from the vicinity of waterways that are practicable in November, the season when the disease is most easily recognized: the hitherto recorded outbreaks in Faridpur and Backergunge are confined to the neighbourhood of large "chars," or swamps that hold water well into the cold weather. It is highly probable that such cases do not entirely represent the truth, that the large areas which are difficult to reach as the paddy ripens, owing to the fall of the water, are equally ravaged by the disease. In further support of this view is the fact that in the Dacca District the villages from which ufra has been reported are mostly accessible in the rains from the high land that extends north of Dacca town towards the Madhupur Jungle, or from the navigable waterways. No report was obtained from the Manikganj Subdivision, less easy of access, until a special search was made in 1917, when it was found heavily infected.

Hence it is quite impossible as yet to form an accurate estimate of the extent of the infected tract or of the amount of damage caused by the disease. The accompanying map gives roughly the limits of the disease as at present known.

The southern limits of the infected area were accurately defined east of the Meghna, in August, 1917. They are, from east to west, the villages near Dhoom just south of the Mahari and Bara Feni rivers (which have been crossed

* I have seen a fair crop of paddy in a field where the measured depth of water exceeded 12 feet.



K. D. Das.

Map showing area known to be infected by the rice worm in 1917 (shaded area.)

District boundaries........................

Railways

Scale: 1 inch = 48 miles.

since 1913), and from thence to the estuary of the Meghna by a line passing to the north of Noakhali town. West of the Meghna, in the district of Backergunge, the disease was found in 1916 from Barisal to the borders of Khulna District at the river Madhumati, but the exact limits of the extension south and east of this area are not known. In the eastern section of this boundary further spread southward is checked by the sea and by the Chittagong Hills and a narrow belt between the hills and the sea where the land is relatively dry and no swamp paddy is grown. No trace of ufra has been found in the swamp paddy areas near Chittagong town. West of the Meghna, the limits so far observed are not coincident with any topographical feature of importance, and there seems to be no reason, beyond the comparatively recent origin of the disease and the slowness of its spread, why it should not extend into Khulna and the Sundarbans, at the head of the Bay of Bengal.

To the east, the infected area is limited by the highlands of Hill Tippera ; but between these and the district of Mymensingh is an area in which extension is going on towards and perhaps into Sylhet. It is known to have reached Akhaura, about 10 miles from the Sylhet border, in 1913. There appears to be no obstacle sufficient to save the very large rice area of Sylhet from infection.

The same applies to the almost equally important rice tract to the north in Mymensingh. Ufra has been traced through Dacca to the Mymensingh border east of the Madhupur Jungle, and probably extends further north. In this direction it is unlikely to be checked by any natural obstacle until the Garo Hills, which bound Mymensingh on the north, are reached.

Westwards, the Brahmaputra is not known to have been crossed north of its confluence with the Ganges. South of this, however, there is a large infected tract on the west of the Padma (as the river is now known), in the district of Faridpur. The western limits of this extension are unknown, but there is some reason to hope that the relatively dry area of Jessore may check westward spread. But extension into Khulna, further south, is, as already mentioned, highly probable, and along this line there appears to be nothing to prevent infection of Central Bengal up at least to the Hooghli.

The immediately threatened areas are, therefore, Sylhet to the east, Mymensingh to the north, and Khulna (with possibly some of the districts across the Brahmaputra) to the west.

As regards the losses sustained only isolated instances can be given. Total loss of the crop in individual fields is not uncommon. I have seen such cases in Noakhali, and the Collector of Dacca saw large areas near Pubail, in 1916,

where the crop was so poor that it was not worth cutting and the cattle were turned loose to graze it. The same officer reported total loss of the winter rice crop in Raban village that year. In Begumganj thana of Noakhali District the loss in 1910 was roughly estimated at 200,000 maunds (about 7,400 tons) of grain. In October, 1913, most of the cultivators in certain parts of Feni were found cutting their winter rice for fodder, as they expected no grain owing to a very severe outbreak of ufra. The average annual loss in the village of Kapasia (north-east of Dacca District) for the four years 1911—14 was estimated by an officer of the Bengal Agricultural Department to be Rs. 55,800, distributed over 1,600 acres of deep-water paddy, or an average annual loss of nearly Rs. 35 per acre. In a limited number of villages further south the same inquirer calculated the loss to exceed $1\frac{1}{2}$ lakhs of rupees annually. In the Portuguese settlement at Nagori, east of the Madhupur Jungle, the average for the four years ending 1914 was said by a Revenue officer to be over Rs. 20,000, distributed over 1,248 acres of cultivated land, of which about two-thirds were annually attacked. This gives a loss of Rs. 16 per acre of the cultivated land or Rs. 25 per acre of that annually attacked. Examples could be multiplied, but enough have been given to show that in certain parts of the infected area the disease has created an economic problem of considerable magnitude since no other food crop can be substituted for the rice now grown. But it is impossible to form any reliable estimate of the total amount of damage caused in the whole tract.

It is equally difficult to form an accurate estimate of the length of time the disease has been known in various parts of the infected districts. Only in Noakhali is there good evidence that it has existed for 20 to 30 years. As the limits of extension are approached, it is quite clear that we are dealing with a new and spreading disease. Many villages have been visited where it has appeared within the last five years, and a few have only recognized it during two or three years. The people between Feni and Comilla say it reached them from the south-west, *i.e.*, from the direction of Noakhali, and on the whole it seems likely that it originated somewhere near the mouth of the Meghna. Whether it reached India from some external source or began by a previously harmless organism developing parasitic tendencies is an interesting speculation. Very many of the so-called "new" diseases of plants have been found subsequently to be endemic in the less explored parts of the world. I have recently[1] collected a number of such cases and brought forward

[1] Butler, E. J. "The dissemination of parasitic fungi and international legislation." *Mem. Dept. of Agric. in India, Bot. Ser.*, IX, No. 1, 1917.

a mass of evidence to show that practically all the new fungal diseases of plants that have appeared in Europe and the United States of recent years are importations. The increasing intercourse with distant parts of the world and the constant shortening of voyages have been the chief factors in disseminating disease. The organism that causes ufra is subject to much the same limitations of extension as fungi ; and it is far from unlikely that it will be discovered in some of the countries with which India is in communication by sea and where the diseases of crops have not yet been investigated.

Incidence of ufra in different types of paddy.

The many hundreds of varieties of paddy grown in Eastern Bengal may be grouped into three main classes. The *boro* or spring paddy is sown in November to January and harvested in April-May. The *aus* or autumn paddy is sown between March and May and harvested between July and September. The *aman* or winter paddy (the main crop) is sown at about the same time as the aus but the harvest is in November-December.

The aman is the chief crop, accounting for over two-thirds of the acreage under rice. The number of its varieties is legion. In any given locality, types will be found suitable for the different levels of land. These levels, though slightly marked, are of the utmost significance in paddy cultivation. The general fall of the land, as in most deltas in the making, is away from the river channels, and the water in the small channels flows away from and not towards the main streams. So also, at least in Noakhali, the land does not slope towards the sea, the coastal belt being generally higher (and therefore growing more transplanted paddy) than the parts lying more to the north. Between the main river channels the surface sinks into basins, but little above sea level. Numerous semi-permanent swamps or " chars " are formed, but the deposition of enormous volumes of silt is constantly changing the outlines of these, and the cultivated margins tend to increase. The deposition of silt is not uniform, and further irregularities are caused by the varying courses of currents during flood time. The hand of man accentuates these differences of level by terracing and embanking ; and a field six inches or a foot higher than those around it will often grow a different variety of paddy. In general, the lowest fields grow the worst kinds, and the cultivator naturally aims at raising his land where he can. Three or more different levels, each with a different paddy, will often be found in one holding.

Nevertheless there are great tracts unsuited for any but the so-called deep-water or long-stemmed kinds. In many places they form the greater

part of the crop. The stalks of these varieties may be up to 20 feet in length and they grow astonishingly fast; it is said as much as 9 inches in 24 hours. The lowest land, where they are found, is subject to early inundation, and the crop is sown broadcast very early in the year, so as to ensure a good start before the flood rises.

At a slightly higher level another large group of forms is found. In Noakhali these are often mixed with aus, each class being harvested as it ripens. In other districts the lower slopes (but not the bottom) of the sloping basins grow these forms, often in several tiers each occupied by a different kind. These are also broadcasted, the date of sowing depending on the level and the consequent normal period of submergence.

It is in these two groups of aman rices that ufra is most prevalent. It is true that other varieties are sometimes attacked, but on the whole it may be said that the disease is found chiefly confined to the lower lands.

The higher levels grow the better quality transplanted group of aman paddy. This group includes the *sail* or *roa* rices, which are the best grown in the district. The flood does not reach these levels until comparatively late in the season, and there is time to grow the seedlings in seed-beds and transplant them out before the water is more than a few inches deep. Indeed, in many places it is possible to take a crop of aus or jute first and then transplant the field with aman in August-September. Some of these transplanted amans, however, are suitable for fairly low ground. Thus in Feni and Chittagong several of the *roacha* paddies can be transplanted when the seedlings are as much as two feet in height and can survive if put in 18 inches of water: these kinds may also be broadcasted.

As a rule, the fields intended for transplanted aman are better cultivated than those at a lower level, and even grow winter (*rabi*) crops of pulses, coriander, onions, and garlic at times, after the paddy is harvested.

No authentic case of ufra in any of these transplanted amans has as yet been seen by the writer, though there have been a few reports of damage in transplanted winter rice in Dacca and Noakhali, and the Feni cultivators say *roacha* may be attacked if transplanted in low land that bore a diseased broadcasted crop the previous season. It is also practically certain that transplanted aman which follows a diseased aus crop may get attacked, judging by statements made to the writer in Noakhali.

Aus paddy accounts for between a quarter and a third of the acreage. It is usually broadcasted, but in relatively high land is transplanted. The straw is short and at harvest little stubble is left, especially in transplanted

fields. In the more recent parts of the delta it is common to grow a mixed crop of aus and aman (called *bajal* in Noakhali), both being broadcasted together early in the season, the aus ripening in July or early in August and the aman in November-December. Very early maturing aus is also broadcasted pure on fairly low land in this district, and after harvest in July is followed by transplanted aman, the water being then only a few inches deep. Ufra occurs frequently in both these kinds of aus, in Noakhali and Backergunge, but not in that which occupies higher land or which is transplanted. In Dacca District aus is rarely (if at all) attacked.

The boro paddy is much less important than the others, occupying only about one-fiftieth of the rice area. It is almost unknown in some districts, such as Noakhali, but in others, such as Dacca, there is a good deal. It is found in the lowest land, where water can be held by embankments during the dry season. As this dries out, irrigation is required, the water being lifted from the permanent channels which form a network throughout the district. The boro fields are thus confined to the margins of the latter. It is always transplanted, except on the mud flats of the main channels where it is sometimes broadcasted. It is not attacked by ufra so far as has been ascertained up to date, though there is an unconfirmed report from Gobindapur (Dacca District) that occasional signs of attack have been seen in January.

Thus, in general, the paddy grown on high and relatively high land, including the whole of the transplanted kinds, escapes ufra ; while of those kinds grown on the lower land, only such as are harvested during the moister half of the year, from July to December, suffer. The explanation of this most important phenomenon is connected with the life-habits of the worm and will be reserved for a subsequent section.

Date of appearance of the disease.

Ufra has been observed in aus paddy in Noakhali District in the first half of June. This is the earliest attack hitherto recorded in the field, the crop having been about 2 months old, broadcasted unmixed aus, growing in about a foot of water and therefore on quite low land. In July and August, as the aus ripens in the southern part of the infected area, the attacks are more frequent. The aman is most severely injured from October to harvest time, but cultivators have pointed out to the writer what they detected as early stages of the disease at the end of July and subsequent dissection has confirmed the diagnosis though the external symptoms were obscure. The second growth which appears in very wet aman fields from December to February

is also attacked, and these attacks have been found as late as the middle of February in Noakhali. Between February and June no case of ufra has been seen under natural conditions, though, as will be described below, it is possible to secure successful inoculations in the laboratory during this period.

It is not easy to detect the early attacks, as the symptoms are not well marked on seedlings or even up to the time the young ear begins to form within the bud. There is little change except a somewhat stunted growth and a pallid appearance of the upper leaves. The most recently expanded leaves are either chlorosed as a whole or are marked by pale longitudinal streaks. They are also somewhat thinner and more flaccid than the normal. But it is only later, when brown marks appear on the leaf sheaths and the ears become altered as described in the previous paper, that recognition is easy.

The length of time after infection has occurred before symptoms can be detected varies greatly according to the age of the plant and to other conditions connected partly with the season of the year. On very young seedlings symptoms of chlorosis have been detected within a week of inoculation. On larger plants it may take from ten days to six weeks before the symptoms are definite. When natural infection results from the stubble left from the previous crop it may take two to four months before the disease becomes evident, and this is the most usual experience in field outbreaks in the infected area. It will be seen below that it is possible to offer an explanation of these variations.

The cause of ufra.

The cause of ufra was ascertained in 1912 to be a hitherto undescribed nematode worm ("eelworm"), which was named *Tylenchus angustus* and described at length in the previous paper. When recorded no other parasitic *Tylenchus* was known which resembled it in its life-history or biology. Recently, however, a serious black-currant disease has been found near Cambridge, England, caused by another previously unknown species, *Tylenchus ribes* Taylor,[1] which has many points of similarity in habits to the rice worm, though morphologically quite distinct. It is evident, therefore, that there are more than one species of this well-known genus of nematodes which are characterized by an ectoparasitic life on the above-ground parts of plants, the individuals remaining on the surface of the parts attacked (without actually entering the tissues as most of the parasites of this group do) and

[1] Taylor, Miss A. M. "Black currant eelworm." *Journ. Agric. Science*, VIII, 1917, p. 246.

feeding by sucking out the juices through a minute hole bored by a tiny spear which can be protruded from the mouth. That other such forms exist besides the two already described is very probable, since they are as readily overlooked by entomologists as by mycologists. They are neither insects nor fungi, nor do they cause any such characteristic symptoms as would lead to their presence being specifically looked for. In spite of their simple mode of parasitism they can, as the rice worm shows, rank with the most harmful enemies of plants yet described.

Tylenchus angustus feeds, so far as can be ascertained, exclusively on living rice. Attempts to grow it in artificial media have failed, and a search through the infected area has equally failed to reveal it on any other plant than rice. It can remain alive, in the absence of food, for considerable periods, but its growth is very limited and no moults occur except those which were due when removed from the living plant. After emergence from the egg there is some increase in size in water, but this never progresses to the first moult The later larval stages increase little, if at all, in water. It is not certain whether the final (sexually perfect) stage can reach full maturity in water if liberated while still immature, but the perfect female may lay eggs for a short time in water. Copulation does not occur in water, as many thousands of adult worms have been kept under observation in this medium without any trace of the sexual act having been seen. In dry air the worm can remain alive for considerable periods, but it remains entirely passive, neither moving, nor feeding, nor growing, nor copulating. There is, therefore, no multiplication of the worm in these conditions, except that a few eggs may be laid in water and a few of these may possibly hatch out into the first larval stage, though as a rule only such eggs as are mature when removed from the plant seem to hatch when totally immersed. Though the worm may remain alive and wander considerably on various solid media for several weeks, no increase in numbers has been obtained in this way, but further considerable trials will be necessary before it can be concluded that artificial culture is not possible.

The worms may be induced to attack paddy at any time of the year if properly handled. Nevertheless there are great differences in behaviour at different seasons, and to understand these it is necessary first to describe the life-history of the parasite when unable to obtain suitable living food.

The non-parasitic life of *Tylenchus angustus*.

Normally the active life of the worm, as indicated by the appearance of symptoms of injury to the plant, extends from June to November in the

southern part of the infected tract, rather later in the northern. At any period during these months it is possible usually to find plants with numerous worms actively feeding. Such worms when removed to water are intensely active, swimming about with great vigour. In swampy ground, where a second growth takes place from the stubble after harvest, this period may be, as already stated, extended to February. But in the vast majority of cases, the parasitic life ceases before harvest in late November or early December.

At this period, as the host plant dries up in ripening, the worms cease feeding, coil up, and pass into a resting condition. The position on the plant which they occupy after the ears emerge is the base of the peduncle, the stem just above the next node lower down, and within the glumes in the ear. Here they may occur in clumps or masses, visible to the naked eye as cottony tufts or a grey coating on the surface of the affected parts, but they are often isolated more or less completely and sometimes very scattered. The species is, therefore, less gregarious in its habits than appears to be the case with *Tylenchus ribes*. Each worm usually forms a separate coil and the coil is usually quite circular (Fig. 1). The tendency to coil is a result of desiccation as a rule, since at any time of year coiling may be induced by drying out the medium gradually. Occasionally coiling has been observed to result from the action of weak poisons, but the ordinary fixatives that are not of rapid action usually kill the worm in an extended position, though there may be a short preliminary tendency to coil.

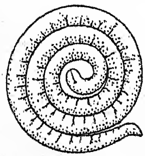


Fig. 1. *Tylenchus angustus*: coiled individual.

After coiling is completed, immersion in water leads to uncoiling. This may happen even after the worm is dead; at least it has often been observed that old coils straighten out in water but undergo no further movement and gradually decompose. The coiled worms are apparently protected in some way (possibly by a mucous coating) from ready decay, and it has often been extraordinarily difficult to decide whether a worm is alive or dead after placing in water. Usually it is safest to rely on the resumption of active motility * for determining that life persists. If the period of desiccation has not been long, motility sets in soon after immersion, but after two months or more in the dry condition it may take over an hour to commence, though uncoiling is usually complete within the hour. To give a specific instance where doubt remained as to the worm being alive, a double coiled worm that had been dry

* By active motility is meant progression, or at least definite wriggling.

for 15 weeks uncoiled slowly to about half of full extension when placed in water. The body was highly vacuolate—indeed almost empty—and no other motion was observed in 18 hours. Yet on adding weak picric acid slight recoiling, to about half the original coil, occurred. Other worms from the same batch decomposed in a few days after uncoiling in water, so that if not dead they were at least moribund. Worms liberated in such a condition in a flooded paddy field would be quite unable to reach the paddy plants or to climb up any that they accidentally come in contact with, so that for practical purposes, in considering the period during which desiccated worms are capable of reinfecting the crop, the resumption of active motility may be taken as a measure. This period exceeds the time required to fill in the gap between the harvest of the aman paddy and the first records of the disease in the aus. Thus worms dried out on their host plants by digging up the latter and removing to the laboratory in the second half of November, 1916, resumed active motility on being placed in water early in June, 1917. The power of uncoiling in water persists much longer, for at least 15 months, but I have not observed active motility after so long an interval, nor would the worm be ever likely to require such a period of rest in the paddy plains of Eastern Bengal before finding conditions of moisture and fresh food which would enable it to resume its active parasitic life.

Life is not so prolonged when the worm is totally immersed in water. Many die in a few days but some may survive for more than a month. The following experiments in 1913-14 illustrate the variations observed. On September 8th, 1913, a number of active worms in all stages were sown in drops of rain water on 4 slides and kept in a moist chamber. The majority were motionless and apparently dead 5 days later. In 11 days all were dead on 2 slides, but a few were still motile on the other 2 slides. The dead ones decomposed gradually and all had decomposed by December 1st when the slides were again examined. On October 9th, 1913, several more slides were similarly prepared but tap water was used. All were dead and decomposing by December 1st (*i.e.* in 52 days). On December 1st, 1913, another batch of 3 slides was prepared in the same way as the last. Many of the worms in all stages were alive and motile after 24 days and about 50 (mostly adults and medium-sized larvæ) after 5 weeks. On January 6th, 1914, from 20 to 30 active worms (mostly larvæ) were sown in a glass capsule in distilled water with some germinated paddy seedlings. The seedlings were removed after 4 days, with one or two worms that had climbed up them. Of those left in the capsule (over 20) only one living could be found on January 26th.

When kept under intermediate conditions between total immersion and dryness, life may be maintained for several months. Kept on slides under bell jars in a saturated atmosphere some have been found still alive after 4 months. Under such conditions they have a certain degree of motility, as will be explained later, and they live decidedly longer than when totally immersed, though less than when desiccated.

Both longevity and motility, away from the host plant, are influenced by other conditions than moisture. Temperature and light are amongst these. In one experiment a number of worms that had been dried on the host plant for two months were sown in tap water on several slides. All the worms were from the same piece of infected peduncle. They were sown on January 29th, 1917, and resumed active motility after about half an hour. Two of the slides were placed in an incubator at 31°C., in a saturated atmosphere, in the dark. Another was kept in a saturated atmosphere on the bench near a window; and a fourth close by under similar conditions except that it was covered with a dark shade. The bench temperature varied from 16° to 19°C. during the next week and then gradually rose, reaching a range of 21° to 23°C. after a month. On January 30th the worms in the incubator were moving actively, as were those exposed to light on the bench, while those in darkness on the bench were very sluggish. The following day these differences were accentuated. The darkened worms in the incubator were exceedingly active, while those in darkness on the bench had ceased swimming and were merely coiling and uncoiling or bending from side to side slowly. Those exposed to light on the bench were swimming a little less actively than those in the incubator. Here both light and warmth had stimulated activity, the latter somewhat more than the former. On the 23rd of February all the worms in the darkened chamber on the bench were dead, while those exposed to light were still alive in fair numbers though now only moving sluggishly and mixed with a good many dead. In the incubator, on the other hand, most of the worms were still living and very active in the water. The drops were replenished on this day. A month later some were still alive and moving in the drops in the incubator. By the 13th May there was only one worm left alive in the lighted chamber at laboratory temperature (now ranging from 27° to 29°C.) and that one had migrated from the drop, while there were still many in the incubator. The water in the latter had dried to a thin film in which no living worms were left, but living worms were scattered over the rest of the slide, singly or in small groups, and feebly motile. On adding water they promptly became actively motile again. As the incubator had now ceased working owing to the rise in temperature, the slides

were kept on the bench exposed to the light, and a few worms remained alive until May 30th. Thus in prolonging life, as in stimulating motion, both warmth and light were favourable, the former more than the latter.

The experiment was repeated during warmer weather, when the laboratory temperature ranged from 30° to 32°C. Worms that had been dried on the host plant for 18 days were much more sluggish at this temperature when kept in darkness than when exposed to light for several days after sowing in water, whereas in another batch, only 7 days after collecting, there was no appreciable difference. This suggests that starvation may also influence activity. All were almost equally sluggish after the worms had lain in water for 16 days. In a cool incubator at 23°C., in the dark, activity was much reduced, but was stimulated even after 4 weeks when warm water was added. Longevity was not tested in this experiment, owing to failure to keep the worms from wandering.

Wandering of *Tylenchus angustus.*

When the study of this worm was first taken up, its remarkable activity in water, combined with its immobility on the plant, led to the hasty conclusion that free liquid was necessary to enable it to wander. The plants were naturally examined in rooms in which the air was relatively dry, and under these circumstances nothing beyond an occasional contraction of the body was noticed when the worms were watched through the microscope on the stem and leaves of rice. It has now been fully established by repeated observation that free liquid is not necessary for travelling, but that the worms can move slowly, but none the less through considerable distances, in a saturated or very damp atmosphere. As this is one of the most important factors in explaining the periodic incidence of the disease, it requires to be further considered.

The first indication of migration in a saturated atmosphere was obtained while drops of water, containing a known number of worms, were kept under observation for long periods on slides in a moist chamber. After one or more days some of the worms were missing. When this had occurred several times, accident revealed the missing worms on other parts of the slide, often near the edge, which they apparently find difficult to pass. If examined immediately on removal from the moist chamber, or in slides prepared as for the well-known "hanging drop" method of examination, they can be seen to move slowly by a snake-like method of progression. On open slides progression soon ceases when exposed to room dryness, but it starts again if the slide be

breathed upon. In moderately dry air, or even under such conditions of humidity as ordinarily occur in the laboratories at Pusa during the monsoon months, movement on a dry surface is apparently impossible. In air that is approximately saturated, moisture is condensed round the body of the worm, appearing as a film or sometimes a minute droplet, in which movement is relatively free. In such conditions worms have been found to pass round to the under surface of the slide, and even to travel on to other slides on benches above or below that on which they were placed in the moist chamber. Not only can they move on dry surfaces in a saturated atmosphere, but they can enter and leave drops of water, though the latter cannot be easy if the resistance caused by surface tension be taken into account. Some batches examined seem to have had a much greater tendency to leave the drop of water in which they were sown than others, and it is tempting to suppose that this is due to a copulatory instinct. At any rate, it has been observed that the worms that have left a drop often come together in twos or threes, and in several cases a male and a female have been found applied together, either extended or partially coiled over one another, though actual copulation has not been seen. Under no other circumstances has the writer observed anything of the kind, and he is fairly satisfied that copulation must take place in a saturated atmosphere, without free liquid, though perhaps confined to worms on the living host plant. It should be mentioned, however, that larval stages have occasionally been seen to possess the same instinct as the perfect forms.

Several of the earlier inoculations carried out at Pusa failed owing to ignorance of the above facts. They were made on plants growing in pots in the laboratory with no precautions to keep the air around the plants near the saturation point. In some the worms were inserted within the leaf sheaths; in others worms or eggs or infected pieces of paddy were placed in water around the base of the plants. Field inoculations carried out in the same way succeeded in every case when performed during the monsoon months. During this period the humidity is always high, and the air surrounding the plants, especially when, as was the case, these grow close together, is probably approaching saturation. It has now been found that to get successful results in laboratory inoculations the air must be kept moist by the use of bell jars or other similar means. Only under very exceptional conditions of humidity have attempts at inoculation within-doors on uncovered plants given any result (*see* Expt. III on p. 20).

We can now understand several of the peculiarities in the incidence of the disease under natural conditions. As already stated, the boro paddy, which is grown during the period from January to April, escapes the disease. This

it does even though the boro fields may adjoin badly diseased fields of aman paddy. There cannot be the slightest doubt, from what I have seen, that boro fields are often contaminated with infected stubble from the aman crop. The boro is transplanted into these fields usually within a month of the aman harvest, and the fields themselves usually occupy the lowest land, bounding the banks of the permanent *khals* or waterways that run through the centre of the rice *bils* along the natural drainage lines of the country. Around them are great stretches of land suitable for the deep-water aman in which ufra is most prevalent. As the boro fields are kept permanently flooded, and as some of the infected aman stubble must certainly find its way into them, their water must contain free-swimming worms. Experiments carried out at Pusa have proved that the parasite is only too ready to attack paddy at this period, provided the moisture conditions are kept suitable. Hence there must be some explanation connected with the conditions of the environment to account for the general escape of the boro cultivation. This explanation is to be found in the dryness of the air between February and May as compared with that of the rest of the year.

The following table, abstracted from data collected by the Meteorological Department (*Ind. Meteoro. Memoirs,* XXII, p. 460), gives the monthly normals of relative humidity at a series of stations in or at the borders of the infected area :—

Monthly normals of relative humidity.

Locality	Number of years	January	February	March	April	May	June	July	August	September	October	November	December
Chittagong	22	88	83	82	80	81	86	88	88	88	89	88	89
Noakhali	22	89	85	84	81	83	88	90	90	89	88	87	88
Barisal	22	87	84	84	82	82	87	89	89	88	84	84	86
Brahmanbaria	6	87	82	79	80	82	87	88	87	86	85	80	84
Narayangunj	22	88	83	83	83	84	89	90	90	88	85	85	87
Goalundo	6	86	81	76	77	79	85	87	86	84	80	79	83

In all stations the maximum rise in humidity (5 or 6 per cent.) takes place between May and June, and in none (except Noakhali in February) does the humidity between February and May reach 85 per cent. Between June and September the humidity remains above 85, except in Goalundo, where it falls to 84 in September. It may be added that heavy night dews persist after the rains until well into February, but thereafter diminish and disappear as the hot weather sets in. Since the records are taken at 8 A.M., it is probable that

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the vaporisation of the morning dews affects the readings, and that midday or afternoon records would give lower relative readings in the early months of the year.

It has already been pointed out that *Tylenchus angustus* lives and feeds towards the top of the rice plant. To reach this position it must be able to mount the plant, emerging from the water at its base and climbing up the parts above water. This it cannot do, as explained above, unless the surrounding air is at a point approaching saturation with water vapour. The same condition is necessary to allow it to spread from one plant to another. No doubt when the boro paddy is first transplanted, some of the worms should be able to make their way between the folds of the leaf bud at the water level and reach a position suitable for feeding and even for multiplying. It is probable that there is some injury to the crop at this stage (the more so since the second crop of aman shoots has been found infected in January and February), but it would not attract much attention ; the symptoms, as already pointed out, are not very definite on seedling plants ; and the injury would most likely be attributed to the check received during transplantation. Once the rice shoots had grown well above the water, further multiplication of the worm would cease, and further infection of the susceptible parts would become impossible, as its migration would be prevented by the dryness of the air ; those worms that had failed to get out of the water would die after a month or two. Thus the characteristic attacks as the crop ripens would fail to develop.

This explanation of the immunity of the boro crop has been considerably strengthened by observations made in 1918 on the second growth of infected aman. A field on the Dacca Experiment Station was found to have the young shoots and dwarf ears that grew from the stubble of diseased winter rice in January (after harvest in December) heavily infected, while those that grew in February entirely escaped. The infected and clean shoots were often within a few inches of one another, yet the worms were unable to reach the latter, though, when immersed in water, they were found to be highly motile. The February attacks observed in Noakhali are probably correlated with the higher humidity of that district.

The same factor serves to explain the remarkable differences that have been observed in the length of time between infection and the appearance of the disease, according to the season of the year and the method of infection employed. In field inoculations carried out during the monsoon, the first symptoms may be observed in about 8 days where the worms are directly

inserted under the leaf sheaths [1] and in about a month when worms are added to the water in which the plants are growing. When infection comes from the stubble of a previously diseased crop, the period depends on the season or, to be more exact, on the humidity. The following are some of the results obtained at Pusa :—

(1) Seed broadcasted in a plot, which contained stubble from a diseased crop of the previous season, on March 28th, 1913. Ufra distinct by the first week in August, though some doubtful symptoms were seen as early as May 12th.

(2) Seed self-sown from a preceding diseased crop in December, 1915, and germinated during the first three months of 1916, coming up through the rotting stubble. Ufra first clearly seen on July 24th.

(3) Stubble removed from a diseased plot on December 3rd, 1913, and seed broadcasted, returning some of the infected stubble, on the same day. As germination was backward and not sufficient to fill the plot, some plants were transplanted into it in January and February, 1914, and some more seed was broadcasted on March 5th. Ufra was first found in a plant of the first batch sown, on June 17th, and was seen in all three batches on July 10th.

Thus whatever time the seed is sown at Pusa, between the beginning of December and the end of March, ufra definitely develops (when the infection comes from worms left in the stubble from the previous crop) only when the air humidity rises after the rains break in June. When sown early, there is little growth before March or April in Pusa, but the worm is not able to affect appreciably even small plants until the air humidity rises enough to allow it to climb up the above-ground parts. That there is no inherent inability in the worm to attack rice during this period is evident from the fact that at any time between December and April it has been possible to secure infections in the laboratory by keeping the plants covered by a bell jar.

It is now easy to understand why it is that, though there is no month of the year during which paddy may not be found growing in some part or other of the infected districts, ufra is confined to the period from June to December. It is practically certain that the worms occur in the water of low-lying areas in the early months of the year, and probably a good many of them reach the growing boro paddy and get carried up or even, since the night dews are heavy

[1] "Diseases of Rice," p. 13.

in January-February, climb up above the water. That they can do so is evident from the attacks observed during this period on second growth aman paddy, though in Dacca, one of the chief boro areas, these have not been observed after January. There is even some evidence, as mentioned on p. 7, that January attacks have been seen on boro at Gobindapur. Those that do not leave the water are probably all dead a month or two after the fields are flooded. While in the water they do not multiply, and after they leave it multiplication can probably only proceed to a limited extent before the air becomes too dry to allow of copulation. They can feed for a time on the young inrolled leaves of the shoot bud, but when the leaf tissues mature feeding becomes impossible, as explained in the next section. The attack on the second growth from swamp aman paddy can be readily detected, as the shoots that spring from the old stubble very soon produce dwarf ears, and the worms congregate in and at the base of these and cause in them the same easily recognizable symptoms as in the main crop as it matures. But in the boro plants only the obscure symptoms of the early attack could be expected, and these are readily overlooked. From February or March on, no further migration would be possible, and the boro plants, though they may possibly bear desiccated worms in their lower parts, escape the injury to the ears and upper part of the stem that causes such losses in the later crops. They are harvested before the break of the rains would allow of further infection. In the same way, the aus paddy does not become severely attacked until June (the infection probably takes place in May), though worms must be present in the water of the lower-lying tracts from the first flooding of the fields. The aman is doubtless attacked at the same time but the attack escapes notice as the crop is still very immature. Worms have been found in the inrolled leaf buds of aman at the end of July, causing little external signs of disease as compared with what they cause in the ripe aus at the same period or in the aman later on ; and there can be no doubt that the invasion of both crops takes place at about the same time. That the damage to the aman is so much greater than to the aus is probably due to copulation only being possible after the rains break. Multiplication has not time to proceed far before the aus is harvested, but can continue for several months during the maturing of the aman.

Parasitic life of *Tylenchus angustus*.

The rice worm can only feed on certain parts of the plants. To those mentioned in the previous paper,[1] *viz.*, the young ear, the peduncle, the part

[1] "Diseases of Rice," p. 15.

of the stem just above the upper nodes, and the leaf sheath, must be added the young leaf blades inrolled towards the centre of the bud above the growing point. When seedling plants are inoculated, the latter is the point where the worms collect. They enter between the folds of the bud (never actually penetrating the tissues) and work their way round these towards the inner layers. Seedlings of about a fortnight from germination and six days after inoculation have been found to contain very many worms under the outer, still rolled, green leaf, and within the succeeding leaves and sheaths right in almost to the growing point. Naturally-infected aman plants have also been found in August, when about half grown, to contain pure cultures of enormous numbers of *Tylenchus angustus* in the white central part of the bud. In this case the plants were $2\frac{1}{2}$ to 3 feet high, and all the leaves were removed until the central white bud, $\frac{1}{2}$ to 2 inches long, was reached, when further dissection became difficult. The last few leaves around the growing point are so tightly rolled that they are not usually penetrated until loosened by the developing ear. Prior to this, the growing point is not reached and the worm feeds chiefly on the young leaves. Here it does not cause sufficient damage to kill the plant or even to cause any very marked symptoms except chlorosis and sometimes stunting. As the leaves mature, the outer cell walls thicken as described in the previous paper and feeding becomes impossible. Worms are scarcely ever found on any but the very young leaf blades, and when found they are probably only migrating, not feeding. It is not until the ear is forming and the worms collect at its base and above the top nodes of the stem that the strain becomes more than the plant can meet. It is quite possible to keep even severely infected young plants growing, but often impossible to get them to bear mature ears.

Feeding is exclusively by sucking out the juices from the epidermal cells of the infected parts. The spear which perforates the wall is only 9 or 10μ long, and is unable to penetrate any but unthickened or slightly thickened cell walls. Microtome sections of young infected leaf buds have not shown any very definite signs of injury to the cell-contents where the worms were feeding. There is no evidence of toxic action, so that the injury is presumably entirely due to continued removal of the cell sap. In other parts, as around the stem and base of the peduncle, the cells collapse and turn brown, but bacteria and fungi so rapidly follow the injuries caused by the worm that it is hard to separate their effects. The lower part of the last internode and the base of the peduncle may be shrunken to little more than the thickness of a thread.

Reproduction undoubtedly goes on vigorously on the plant during the period from June to November. Eggs and larvæ in all stages are found mingled

with adults within infected leaf buds and around the young ear. The length of the larval stages and the time that elapses from egg to adult has not yet been worked out either for the rice worm or for the allied *Tylenchus ribes*, so that there is no guide as to the rate of multiplication, but it is undoubtedly great.

Some of the inoculation experiments carried out at Pusa since the previous paper may now be described. Some of the earlier failures (I and III) are given as they led to the discovery of the close relation between atmospheric humidity and infection.

I. 28-3-'13, sowed paddy in 6 pots. 12-4-'13, seedlings numerous, about 6 inches high. Water was kept standing about an inch deep on the surface of the soil, which was puddled clay. Inoculated 2 pots by inserting pieces of infested peduncles and internodes bearing many worms under a leaf sheath. The material used had been desiccated for 5½ months in the laboratory. Inoculated 2 other pots by placing some of the same material in the water at the base of the plants. The remaining pots were kept as controls. During the following month dissected several of the plants in the inoculated pots and found in those inoculated through the water a few worms resembling *Tylenchus angustus*, some at the base and others within the shoot bud higher up. No ufra symptoms developed and the plants grew to maturity and headed out normally, giving 15 to 20 good ears in each pot in November. The plants were kept on a dry verandah, not covered, and the failure to develop an attack of ufra was doubtless due to this. The average of the 8 A.M. relative humidity recorded at Pusa during the two months after inoculation was 62·9 per cent.

II. 27-5-'15, sowed paddy in 24 pots. 28-7-'15, inoculated 12 of these with freshly collected (4 days old) aus paddy from Noakhali severely infested with *Tylenchus angustus* by placing pieces of diseased stems and ears in the water at the base of the plants. 10-8-'15, one of the inoculated pots showed definite symptoms of ufra. 14-9-'15, ufra distinct in 9 of the 12 pots and minor symptoms visible in the other 3. *Tylenchus angustus* present in quantity on the diseased plants. No symptoms and no worms in the 12 control pots. The plants were kept out of doors, and the success is to be attributed to the monsoon conditions to which they were exposed after inoculation. The average of the 8 A.M. relative humidity recorded at Pusa during the two months after inoculation was 86·1 per cent.

III. 30-12-'13, sowed paddy in 4 small pots (about 3×2 inches) and thinned to 1 plant each. Kept in incubator at 30°C., lighted through glass door. After about a week (when the seedlings were 2 inches high) inoculated 3 of the pots with motile worms, 2 being done with worms that had been swimming in water for a month, the third with worms freshly taken from a growing plant attacked by ufra. No infection resulted and not a single worm could be found to have ascended 2 of the plants which were dissected a week later. The third (one of those done with free-swimming worms) equally showed no signs of infection but was not dissected. The plants were kept in the incubator, the air inside which was dry except for the small amount of evaporation from the surface of the pots. Similar results were obtained when germinated seedlings were placed on 7-1-'14 in a glass capsule in the incubator with a few c.c. distilled water to which were added some 20 or 30 motile worms fresh from the diseased plant. Only 1 worm succeeded in climbing up a short distance up one of the shoots. Other experiments in which adults and eggs were used to inoculate seedlings in 6 of the small pots equally failed. They were kept uncovered, remaining indoors until the plants were too big for the pots

when they were transplanted with all the soil into larger pots on the verandah. So long as the humidity round the plants is not kept at a high level, infection cannot be secured. Occasionally, however, the natural monsoon humidity rises to a point, even within doors, when motion becomes possible and the plants can be climbed. Thus on 21-8-'17, two shoots were placed with their bases immersed in a few c.c. distilled water containing worms, the shoots projecting about 4 inches into the air. They were left on the bench, uncovered. By the 26th they were distinctly chlorotic, and on dissection were found to be full of worms in the bud folds right up to the apex. The 8 A.M. relative humidity recorded at the Pusa meteorological station averaged 87 per cent. for the five days the experiment lasted, while in the laboratory it exceeded 90 at 7 A.M. on most days, falling however to 80 or lower by noon. A similar experiment on 4-9-'17 only yielded a few worms in the basal half-inch, none having reached the upper part, when dissected 3 days later. This was a drier period than the last, the average 8 A.M. humidity having fallen to 83.

IV. 1-12-'15, sowed paddy in a glass basin in ½ inch distilled water, together with freshly collected actively motile worms, and kept covered so that the air remained saturated. 13-12-'15, found many living worms collected on a piece of young paddy leaf in the water and placed this in contact with one of the seedlings at water level. 19-12-'15, this seedling distinctly chlorosed. Examined and found heavily infected above the water level. 3-1-'16, many of the seedlings now well infected and the worms found in the shoot above water in all the inner layers of the leaf bud. 22-1-'16, repeated the experiment in two other basins, using seedlings 19 days from sowing. 27 to 30-1-'16, infection successful in seedlings of one basin, and 31-1-'16 in those of the other. Shoots chlorosed and worms found in the bud layers well above water.

V. 22-1-'16, transplanted 3 seedlings, 19 days from sowing in water, into each of 4 small pots. Kept standing in water covered by bell jars. 28-1-'16, inoculated a pot containing 2 seedlings (the 3rd had failed to survive transplantation) by inserting pieces of the inner white shoot bud of seedlings from the last experiment, containing worms, between a partly expanded leaf and the shoot. 23-2-'16, both the inoculated seedlings dying, having shown symptoms of attack about a week after inoculation. Only one *Tylenchus* could be found on dissecting the plants, the others having probably left the drying plants in search of fresh food. Of the 9 uninoculated seedlings, 1 was attacked by fungus (*Helminthosporium Oryzæ*) and the rest were perfectly healthy.

VI. 2-1-'17, sowed paddy in distilled water. 29-1-'17, transplanted 2 seedlings into each of 2 small pots, in one of which buried (about ½ inch below surface of soil) a few empty florets containing *Tylenchus angustus*, from plants from a plot that had ripened in late November and had been left in the field. Kept standing in water, covered by bell jars. 21-4-'17, examined the plants. One of the seedlings in the inoculated pot was apparently healthy and contained no worms; the other had brown stains on the sheaths as in ufra and there were a good many active *Tylenchus angustus* in the inner layers of the shoot. The 2 seedlings in the uninoculated pot were healthy and had no *Tylenchi* on them.

VII. The plot inoculated at Pusa in August-September, 1912, as described on p. 13 of the previous paper, ripened at the end of November and was a good deal damaged by ufra. It was left until March 28th, 1913, when the stubble both in it and in the uninoculated plot was cut and dug in to a depth not exceeding 3 inches. Local seed was sown the same day in both plots. Water was run on and kept standing as usual in paddy growing. By August there was a marked difference in the two plots, that previously inoculated being about 6 inches lower than in the other and

somewhat thinner. Numerous typical cases of ufra in the early stages were present in the former, and a few in the latter near the boundary (a 6-inch bund) between the two. In some plants it was estimated that between 500 and 750 worms and 200 eggs were present in the inner layers of the shoot bud, above the growing point, in greatest numbers about 3 or 4 inches above the latter. The photograph reproduced in Fig. 2 was taken on September 9th. Scarcely any crop was got

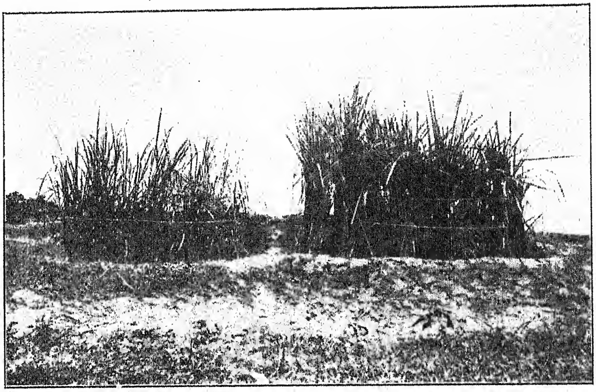

Fig. 2. Condition of the paddy plots in Experiment VII on Sept. 9th, 1913. The plot on the left is that originally inoculated.

from the inoculated plot, while about a quarter of the other was damaged. The stubble was left as before until the beginning of April, 1914, when it was all carefully hand-picked off and destroyed. On 7-4-'14 both plots were re-sown with local seed. No ufra appeared and a normal crop ripened in the last week of November.

VIII. The inoculated plots at Dacca, described on pp. 11–13 of the previous paper, were harvested in December, 1912, and the stubble destroyed, the plots being burnt over carefully. Paddy was grown on these plots without any trace of ufra, up to 1917, when they were sown with seed from an infected field as described under Experiment XI.

IX. Three small plots were transplanted with paddy seedlings early in the rains in 1913. 8-9-'13, 20 fresh infected central shoot buds from Experiment VII, with the outer leaves stripped off, were pinned down in the water channel near the inflow to the middle plot. The other plots received water from the same channel by inlets, one higher up and one lower down. 9-10-'13, the plant nearest the inlet in the central plot was removed. It had chlorosed shoots but no brown stains. It was found to be heavily infested in the inner layers of the shoots. 7-11-'13, the central plot now totally infected and signs of spread into the other two. 1-12-'13, the central plot almost all dried up and with little grain. In the other plots most of the plants were in ear, but there was a good deal of injury and some plants were barren. The photograph reproduced in Fig. 3 was taken

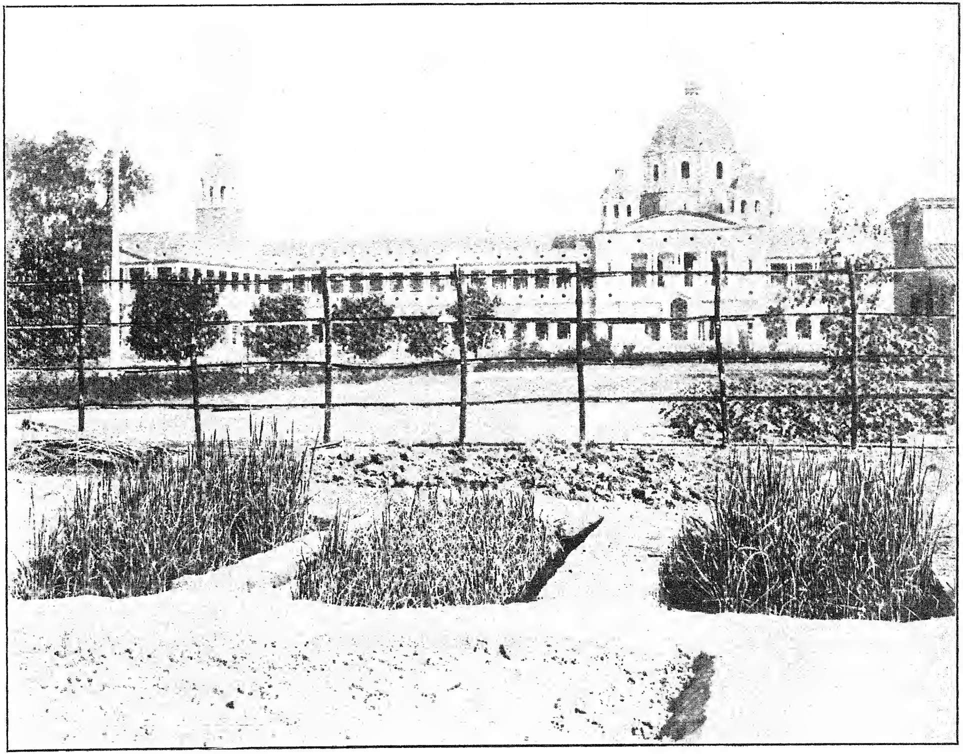

Fig. 3. Condition of the paddy plots of Experiment IX at the end of Nov., 1913.

at the end of November, 1913. 3-12-'13, the stubble was cut and the plot re-sown, some infected stubble being returned after sowing. Further details are given under Experiment III on p. 20 above. Ufra was well developed in July, 1914, and the photograph reproduced in Fig. 4 was taken on August 21st. On August

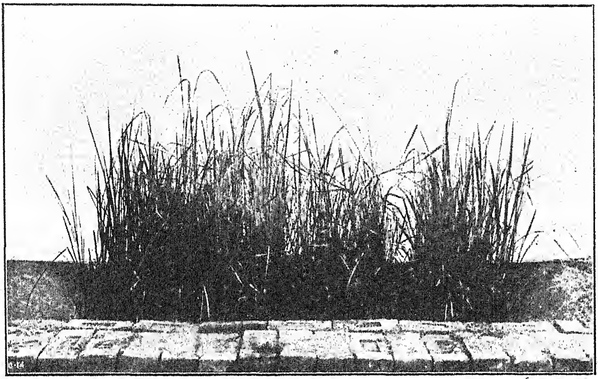

Fig. 4. Condition of the centre plot of Experiment IX on Aug. 21st, 1914.

26th the crop was burnt on the ground with kerosene oil and a fresh crop (both transplanted and broadcasted) put in on August 29th. This grew well and headed out normally in November with no trace of ufra.

X. Four plots were sown with paddy on May 24th and 25th, 1915. 28-7-'15, two of the plots were inoculated by placing fresh diseased shoots (4 days old) in the water. 15-8-'15, a few plants showed symptoms and were found infected with worms. 8-11-'15, the disease now well developed, almost all the plants being attacked in one plot, while the other contained numerous scattered cases. The soil of the latter was rather porous and the water-supply not well maintained on its surface. It ripened a moderate crop in December and was allowed to shed its grain, which germinated as mentioned above in Experiment II on p. 20. A permanent supply of water was arranged from July, 1916, previous to which it had been only watered intermittently. Ufra appeared in July, 1916, scattered plants showing chlorosed shoots without brown stains. One was examined and found infested with *Tylenchus angustus*. 22-11-'16, a good many plants had now well-marked ufra and were heavily infested. In the other plot the disease had been so severe the previous year that there was little grain produced and the self-sown plants were very few. 26-7-'16, transplanted a number of seedlings into this plot, but did not run in any water, so that the soil remained dry except when wetted by rain. There were some early signs of ufra in the self-sown plants in July, but the attack did not develop further and when harvested there was no evident disease and no trace of worms could be found in a large number of plants examined. The other two (uninoculated) plots remained healthy throughout. Here it would seem that standing water or at least a permanently wet soil is

necessary to allow an attack of ufra to develop. The stand of paddy in the "dry" plot was never strong and this may have helped to prevent an attack by keeping the air humidity in the plot at too low a level to allow of free migration. 3-2-'17, cut all the stubble in the "wet" plot and its control, discarding the "dry" plot and its control from further experiment. The stubble from the "wet" infected plot was stored in bags in the laboratory, while that from the control was burnt. The plots were then ploughed up. 2-4-'17, sowed local paddy seed in a seed bed. 5-7-'17, transplanted this into the "wet" plot and its control. 31-7-'17, returned the stubble that had been preserved in bags to the control plot, leaving the other untouched. No ufra developed in either plot, the plants heading out normally and giving a heavy yield in December. When the stubble was removed from the bags for use in inoculating, it was found to have rotted badly and to be powdery and damp. A number of the diseased ears were examined microscopically, and though they contained plenty of dead worms not a single living one could be found. The method of storage had obviously killed them, but the experiment at least confirmed the efficacy of removing the stubble and early ploughing in checking infection from the previous crop.

XI. The isolated plots at Dacca referred to as Experiment VIII were sown with seed taken from an infected field in 1917. Ufra developed towards the end of the rains and destroyed about a quarter of the crop.

The above experiments bring out certain points very clearly. No matter when the worms reach the field, ufra only develops in the monsoon unless the plants are kept covered so that they grow in a saturated atmosphere. When covered, an attack can be induced even in the cold, dry part of the year (Expts. IV and V), or later when it is still drier and very hot (Expt. VI). The attack is readily induced by leaving infected stubble from a previous crop on the field (Expts. VII and X), or by adding infected shoots to the water (Expts. II, IX and X). If the stubble be carefully hand-picked off or the infected crop burnt on the field, a perfectly healthy crop of paddy may be grown in soil that bore a severely diseased crop the previous year (Expts. VII to X). If the paddy is grown under "dry" conditions, an attack may be avoided even where there is infected stubble from a previous crop in the field (Expt. X), but the stand is poor and this may help to keep the air in the crop too dry to allow of migration even in the monsoon. In any case paddy cannot be successfully grown under such conditions. Infective matter does not remain in the soil if all the stubble be removed (Expts. VII and X), even though it can scarcely be doubtful that the worms have, to some extent, been set free in the soil by decomposition of fallen pieces of stubble. Infection may be carried by the seed under certain conditions, provided that (as must often happen) the seed is from a diseased crop and contains infected grains and empty florets (Expts. VI and XI).

As these last two points are of exceeding importance when considering methods of checking the disease, they may be further examined.

The soil in Experiment VII was allowed to dry out more or less completely (so far as the Bihar alluvium does so, which is only in the top few inches) between December, 1912, and March 28th, 1913. It was very much drier than some of the lower levels of the swamp paddy soils of Eastern Bengal at the same period. These may be still quite muddy at the end of February. So also in Experiment X the soil was kept dry from February until the rains in June.

The experiments detailed earlier are strongly against any infection from the soil being possible where standing water persists for several months after harvest; while those just described are applicable to the cases where the fields dry out, as the great bulk of them do, in the early months of the year; but they leave open the question whether the worms may not survive in muddy patches long enough to infect the succeeding crop. It has already been proved that they can live for at least 4 months if kept damp but not immersed in water, and this, combined with the fact that it is just in such muddy places that the second growth from the aman occurs on which ufra has been found as late as February, would be long enough for the purpose. But against this it may be argued that these low-lying places are amongst the first to be flooded by the rising water and such flooding would probably drown most of the worms, already weakened by their long fast, before the humidity rose enough to allow infection to take place. The problem presented by these muddy patches will be returned to below.

As regards seed infection, there is a good deal of evidence that it is not common. Seed from an infected crop has been sown several times at Pusa and at Dacca without causing an attack to develop. In Experiment VI the infected seed was buried in the soil at the same time as the seedlings were transplanted into the pots. The humidity conditions were such that the worms on resuming activity in the wet soil (there was no free water standing on the surface) could migrate to the seedlings. In another experiment the infected seed was buried on December 1st, 1913, and standing water was maintained for about 20 days, after which the soil was allowed to dry out for 18 days. On January 7th, 1914, 3 germinated paddy seedlings were sown in the pot and no infection was obtained though they were kept in a saturated atmosphere in standing water. In actual practice the conditions of Experiment VI are probably never realized. Broadcasted seed is never sown during the monsoon, but only in the earlier months when humidity is too low to allow of migration of the worm. In the monsoon months only transplanted paddy is put out and this could not carry contaminated seed. Again, in Experiment XI, deep-water paddy from an infected field was sown on January

1st, 1917. Owing to danger of infecting lower levels intended for paddy cultivation, the outlet to the water from the experimental area was kept closed. Sowing was done at an unusually early date. The young seedlings were doubtless readily climbed by the worms during the first month of their growth, since we know that the second growth shoots in infected fields that spring from the stubble after harvest are commonly infected in January. The water from the spring showers was held in the field, and though I am not in a position to judge of the effect of this on the humidity within the crop, it can hardly have been without some effect. I am, therefore, of opinion that there is still room to doubt, in spite of this apparently conclusive experiment, whether the use of seed from an infected crop is attended with much danger of conveying the disease under the normal conditions of cultivation. It is clear, however, that the disease can be conveyed by the seed and the exact conditions necessary to enable this to occur must be further inquired into.

The relative immunity of transplanted paddy.

As already stated transplanted paddy ordinarily escapes ufra. The explanation of this as regards the boro paddy has already been given, but this explanation does not apply to transplanted aus and aman.

Transplanted aus is chiefly found in high land in which the water is held by embankments. The fields are fed by rain water or by the surface flow from higher land. The general flood spill from the rivers does not reach these levels at all during the growth of the crop, and after harvest, when the bunds are not maintained, the transplanted aus fields are dry enough to walk through. Thus, unlike the great bulk of the rice lands, fields that bear this class of aus are dry for the greater part of the year. Furthermore, the stubble is very scanty as the plants are cut near ground level. Thus, even if the transplanted aus were to get infected, few worms would be left behind in the stubble after harvest, since they are very rarely found near the base of the plant, and these would have to survive a period of drying on the soil of some nine months before a new crop became available. This they might conceivably do if they remained in protected positions within the sheaths and glumes of the stubble, but such well-protected parts are mostly removed during harvest and any worms left behind would be likely to be set free into the soil by the heavy rainfall after harvest. Thus the conditions would ultimately be the same as have been proved by Experiments VII and X to free infected plots from the disease.

The same arguments apply to the bulk of the transplanted aman, except that the period between harvest and transplanting the new crop is less by

perhaps a couple of months. The fields intended for transplanting are very well prepared by ploughing in the spring as compared with those in which the broadcasted varieties are grown: being relatively high, they dry out early; and any stubble left is well ploughed in and soon decomposes. Where transplanted aman follows jute they are, in addition, usually flooded with at least a few inches of water for a couple of months before transplanting is done. This would be likely to finish off any worms that might have survived. But as stated on pp. 7 and 8, there are certain cases in which transplanted aman is reported to be attacked. The best authenticated are where the crop is transplanted in relatively low land, as in the areas in Feni where either transplanting or broadcasting is done according to the season, and in those in Noakhali where aman follows low-level aus. In the former case *roacha* is sometimes transplanted in land that is so low that transplanting has to be done into 18 inches or so of water, special varieties that will stand this depth being used. Where the former broadcasted crop was diseased, the transplanted is said also to get attacked. In such low land it is probable that conditions are more like those of the deep-water areas than the usual "sail" lands, and they probably do not dry out sufficiently for cultivation until relatively late in the year. They seem to differ but little from the conditions already known to lead to disease in the broadcasted crop. Where aman is transplanted after broadcasted early aus in Noakhali, the new crop is put in about a fortnight after the aus harvest, into water that must contain free-swimming worms if the aus has been diseased. The humidity conditions at the time are entirely suitable for migration on to the new seedlings, and the latter cannot be expected to escape. Except in such cases it is hard to see how ufra could be carried over from one transplanted crop to the next, unless conveyed in the seed, and this could only cause damage to the seed-bed, which is usually sown when the humidity is too low to permit migration.

The control of ufra.

There is as yet no indication that any variety of paddy is naturally resistant to the attacks of the rice worm. The number of distinct varieties grown is enormous and probably only a small proportion of them has as yet been exposed to infection, either natural or through artificial inoculation. Still there has been no report that any of the numerous kinds of deep-water aman grown within the limits of the infected tract can escape, the nearest approach being some of the "digha" or "Aswina" varieties, which mature early and so avoid attack to some extent. With these there is no question of natural immunity, but they merely do not give sufficient time between

infection and harvest to allow of much multiplication of the worms. The late *dighas* are liable to damage, as has been found in the case of the kind known as *aghani digha* in Backergunge. In the Feni Subdivision of Noakhali, an early maturing, long-stemmed variety called *haroli*, which ripens early in October, is grown in land where the water is liable to subside early. This kind suffers less from ufra than any of the other long-stemmed amans of the district, not because it is resistant but merely because the crop is well advanced when the disease usually begins. So also the boro paddies escape not because they are immune but because they grow at a season when the air is too dry to allow the worm to migrate ; and the transplanted aus and aman varieties because they have little stubble after harvest and their fields are dry for much of the year. In every case that has been examined hitherto the reputed resistance of a particular variety or class has failed to stand closer test. Thus there is a variety of broadcasted aman called *khama*, much grown in Dacca District, which was said not to get the disease. Exposed to artificial inoculation it proved as susceptible as any other. It is usually grown on the sloping sides of the paddy *bils*, where early cultivation is possible after harvest, and it has been found that fields intended for *khama* paddy are usually already broken up and their stubble buried at the end of December or early in January. The straw is not very long, and the amount of stubble is decidedly less than in the kinds grown in the bottom of the *bils*. After ploughing, it decomposes quickly enough to expose the worms to a period of life in relatively dry soil which seems to be too long to enable them to survive until the following crop. Aus paddy is reputed to be immune in Dacca District, but the immunity is only apparent and is due to aus being grown on higher land in this area than in the more recent parts of the delta. Aus is often attacked in Noakhali and Backergunge. Even the transplanted amans, which escape in practically all parts of the infected area, have been reported, as mentioned in the last section, to take the disease sometimes when grown in relatively low land, and they are readily attacked if artificially inoculated.

Indeed it is scarcely reasonable to expect any such natural immunity to ufra, amongst varieties of paddy, as occurs so usefully amongst plants subject to fungal diseases. The rice worm is a coarse parasite as compared with most fungi. It never enters into intimate relations with the life of the host plant as so many fungi do, and instead of having to rely on enzymes to dissolve for itself a passage into the tissues (enzymes being bodies notoriously susceptible to alterations in the composition of the medium in which they work), the rice worm bores a hole in the cell wall mechanically with its spear. Unless there exist paddies with such thickened or hardened outer cell walls that the

spear cannot pierce them, it is little likely that immune varieties will be found.

In the earlier paper an extension of the growing of transplanted aman paddies was advocated. It was not then fully realized that the escape of the transplanted kinds in a sense accidental, being due to the relatively high levels at which they are grown, the early and good cultivation of the soil, and the late season at which they are put out. Now that it is known that there is nothing inherent in the transplanted varieties which makes them immune, and that transplanting does not cause the slightest difference to the course of an attack, other things being equal, this recommendation must be modified. The transplanted paddy is usually planted out several months later than the broadcasted is sown. This would no doubt give a long enough period, provided the soil was either cultivated or flooded, to kill out any worms left from the previous crop. But by that time the water would be too deep on the low-lying lands subject to ufra to allow of transplanting. Even if it were practicable, which it is not, it would be no use trying to avoid losses from ufra by transplanting paddy before the rains break into the fields which ordinarily get the disease. The worms liberated from the stubble at the first flooding would attack the transplanted crop as soon as the humidity rose sufficiently to allow of migration, just as readily as they attack broadcasted plants. Thus it is chiefly in the relatively small area in which the level can be altered so as to bring land that previously grew the broadcasted kinds to a height suitable for growing transplanted paddy that any benefit can be expected to result from transplanting.

Hence there seem to be only a few cases in which beneficial results may be expected through attempting to alter the varieties sown in ufra-infected land. One is the introduction of early maturing kinds, such as the *digha* paddies and *haroli*, and the other is re-arranging the levels of particular fields so that they may grow boro, *khama*, or transplanted aman, in place of long-stemmed aman. Mr. G. P. Hector, Economic Botanist to the Government of Bengal, to whom the first of these suggestions is due, is engaged in testing its practicability in certain areas ; while the second is of very limited application and is already well known to the ryots in many places. It will be referred to again below.

The growing of jute in some classes of infected land has been advocated with the idea that if the paddy crop could be replaced even for a year the worms would doubtless die out. In Noakhali a more profitable and, so far as can be ascertained, equally effective practice is to take first a crop of jute and follow it by a crop of transplanted aman put in in August. This cannot be done on the

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lowest land, both because jute does not give good fibre if too early submerged and also because paddy cannot be transplanted if there is too much water. It is true that jute is often grown in land so low that there may be several feet of standing water at harvest time. In this case, however, no transplanted rice can be grown. Still, the moderately low land on which broadcasted aus can be grown is sometimes double-cropped with jute and paddy. The long period after the harvest of the previous crop, especially since the fields are flooded for probably a couple of months before the paddy is put in, is evidently enough to kill the worms. Wherever jute can be grown on land liable to ufra, its cultivation should be recommended once every few years.

Mr. Hector has found that it is more profitable, in some of the areas in Dacca District where broadcasted aus and aman are grown as a mixed crop, to replace the mixture with a pure crop of broadcasted aus followed by transplanted aman. In Noakhali and Backergunge, where both the constituents of the mixed crop get ufra, this practice would not be likely to reduce the disease: the transplanted aman would be infected from the aus. But in Dacca, where the aus escapes, the replacement of the broadcasted aman by a transplanted crop, put out several months later, should appreciably reduce the damage.

It has been amply demonstrated that the stubble from a diseased crop is exceedingly infective if allowed to lie on the soil until the sowing time approaches. In the greater part of the infected area little use is made of the stubble of deep-water paddy. The crop is harvested leaving all but the top foot or so behind, and what is left is not regarded as good fodder and is rarely gathered for the purpose. In the majority of the fields it is left to rot on the ground, and a thin crop of grass comes up through it and is grazed by the cattle. The result is that the stubble is trodden into a matted mass which keeps the surface of the soil moist in the early part of the year. In this condition it resists decay for a considerable time. Even when the fields are ploughed—often not till February—long wisps of half-buried stubble can be found in them. In some places the stubble is sold to the potters for fuel and ash, and the field may, in such cases, be fairly well cleared in December. In other parts a certain amount is removed and burnt in the fields or more usually as fuel in the villages. But in most of the really severely diseased areas little is done to clean up the lowest fields after harvest.

Experiment and observation alike show that if a field can be reasonably well cleared of stubble and then ploughed and kept dry for two or three months the worms can be killed out. Complete destruction of the stubble as in Experiments VII to IX is scarcely practicable under field conditions, but it is

quite possible to remove all but broken fragments and plough these in early so that they have time to decompose, as in Experiment X.

As the disease does not occur naturally in the neighbourhood of Pusa, only small plot experiments under very complete control have been practicable there and no field trials on a large scale could be made. Within the infected tract, field experiments and demonstrations have been hampered for want of trained staff; still something has been done to encourage clean cultivation amongst the ryots and, incidentally, certain difficulties in particular classes of land have been revealed.

The first field experiments * were started at Begumganj in Noakhali District in 1912. Three plots were selected, in one of which the stubble was burned on March 10th, 1912, in another it was burned on the same day and lime added at the rate of 30 maunds per acre a few days later, and in the third liming alone was tried, the stubble having been already ploughed in. The fields were then ploughed and the usual mixed crop of broadcast aus and aman (*bajal*) was sown in the limed plots while unmixed aman was broadcasted in the other. Early in August I visited the plots and found the aus ripe and perfectly healthy. Ufra first appeared in the unmixed aman in October, nearly a month after it was virulent in the surrounding fields. The latter were totally destroyed while the experimental plot gave a moderate yield. No attempt to check infection from the adjoining fields was practicable and the indications pointed to this as the source of the disease.

In 1913 a further experiment was made at Begumganj, the stubble being burned in two duplicate 1-acre plots of infected land after harvest in December, 1912, and then well ploughed and harrowed. Each plot was divided into 4 equal plots at sowing time (March 1st, 1913). One plot was sown with broadcasted aman, a second with the usual broadcasted aus and aman (*bajal*) mixture, a third with broadcasted aus which was followed by transplanted aman, and the fourth with jute similarly followed by transplanted aman. The three last plots escaped ufra, while there was some damage to the first. The yields were at the rate of 14 maunds per acre in the first plot (taking the mean of the two duplicates), 25 (13 aus + 12 aman) in the second, 34 (14 aus + 20 aman) in the third, and 12 maunds jute with 10 maunds rice in the fourth. Hence the damage cannot have been very great even in the attacked plot, of which only about one-tenth of the area was affected.

* All the field experiments in this section were arranged by the Bengal Department of Agriculture, to test the recommendations made by the writer in his previous paper and from time to time since. They were carried out under the supervision of Mr. G. P. Hector, Economic Botanist of that Department, in consultation with the writer.

In 1915 the experiment was continued in one of the two duplicate plots only. The treatment and cropping were the same as in 1913, except that the seed was not sown until April 10th and 11th. The crop on the first plot was destroyed by a flood. The second gave $16\frac{1}{2}$ maunds aus but only a little over a maund aman, the latter having been almost destroyed by the flood. The third gave $22\frac{1}{2}$ maunds aus and $12\frac{1}{2}$ maunds aman. The jute in the fourth plot was much injured by flooding and only gave 3 maunds, while there was a yield of 17 maunds rice in this plot. All the figures are calculated to the acre. There was no ufra in any of the plots nor in any field immediately adjoining them, though there was some not far away.

In 1913 an experiment was made at Bikrampur in Dacca District. There had been total loss of the winter crop in 1912, and a somewhat similar state of affairs had prevailed, according to the local people, for several years previously. Seven acres of land in the middle of this infected area were marked off and the stubble burned in December, 1912. The area was then ploughed and harrowed five times between December 23rd, 1912, and February 12th, 1913. From March 12th to 20th the usual local mixture of broadcast aus and aman was sown after floating off the light grains in salt water. One acre in the middle received 20 maunds of lime also, a month before sowing. The crop was damaged by the rice Hispa, especially on the limed plot, but the yield was $44\frac{3}{4}$ maunds aus and $76\frac{1}{4}$ maunds aman, or a total of over 17 maunds per acre, which is quite a normal crop. No ufra appeared and the owners stated that it was the first normal crop they had harvested for some years. There was a lot of ufra in the surrounding fields, though it was said to be much less than in former years. Hence the experiment was not considered by Mr. Hector to be conclusive.

The Bikrampur experiment was continued in 1914, but no lime was added. Seven acres in a block were selected as before, the stubble burnt in mid-December and the land well ploughed between January and sowing time, which extended from March 13th to the first week in April. Five acres got the usual mixture of broadcasted aus and aman, while the other two were sown with jute and broadcasted aman mixed (a local practice). No ufra appeared and the yields averaged $11\frac{1}{2}$ maunds each of aus and aman per acre, together with $17\frac{1}{2}$ maunds per acre of jute.

In 1917 the experiment was repeated on a larger scale in over 50 acres in 5 separate blocks. Most of the area got deep-water paddy, but a little grew mixed aus and aman or jute and aman. The aus was free from disease, but about 12 acres of the aman, scattered through the 5 blocks, got attacked by ufra. The extent of the damage was not reported.

Around Nagori village, where the disease is extremely severe, 25 acres were brought under treatment in 1917. The treatment was simple stubble burning, with perhaps somewhat more thorough ploughing subsequently than is customary. Deep-water aman and *digha* paddy were sown. A good harvest was obtained, only 3 acres being attacked by ufra.

In 1916 field trials of the effect of burning the stubble in infected land were carried out under the orders of the Collectors of Tippera and Dacca.

In Tippera trials were made in the Chandpur and Sadar Subdivisions. In the former 64 plots of land were treated, comprising in all about 46½ acres. The stubble was burned after harvest and the land ploughed 10 times before sowing. There was no expert supervision of the operations, and no further details of the treatment were given. Nine of the plots were slightly affected by ufra, the rest escaped. In the Sadar Subdivision 12 plots, comprising nearly 11 acres, were treated. They included high, low, and intermediate levels. Some had been damaged by ufra for 5 or 6 years continuously, some for 2 or 3 years, some in alternate years. The stubble was burned after harvest and the land ploughed and harrowed 15 to 18 times before sowing. No ufra appeared in any of the plots, though one had an affected plot adjoining it. Still ufra was little prevalent in the district around in 1916, having only been reported to have damaged 30 acres in 12 square miles. There had been a flood of exceptional intensity in the monsoon of 1915, and a great deal of deep-water paddy was lost. This seems to have had a remarkable effect in reducing ufra the following year. It is probable that there was little contaminated stubble left to carry over the disease to the following crop.

In 1917, 14 acres near Laksam were treated as in the previous year. No ufra appeared, though in one case there was an attack close by. The disease remained relatively mild in the surrounding tracts.

In Dacca experiments were carried out in two widely separated areas in *bils* running into the high old-alluvium of the Madhupur Jungle. One of these, the crop in which had been severely attacked by ufra in 1915, was "bunded" across at the point where it debouched on the plain. The stubble was burned a considerable time after harvest, and as late as March 1st, 1916, the ploughing was still incomplete and the bund unfinished. As a result, the seed was broadcasted between six weeks and two months later than customary and the water rose before the plants were high enough to withstand injury. No ufra appeared, but the harvest was poor owing to the defective treatment the crop had received. Unfortunately here again there was little ufra in the immediate neighbourhood, the nearest diseased patch found being about ¼ mile away.

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In the following year the bund was maintained and the experiment was supervised by the Agricultural Department. Sowing was done at the right time and a good crop, free from ufra, was obtained.

In the other area the *bils* selected were at a very low level and had suffered very severely from ufra for several years. The stubble was reported to have been burned in December, 1915, and the land ploughed early. The writer, however, examined the conditions in December, 1916, and concluded that it would be quite impossible to burn the stubble effectively in these particular *bils* so soon after harvest. In December most of the fields reported to have been burned were found to be still too swampy in the lower levels to enter, and even on February 28th, 1917, the central parts were still damp and soft. It would have been quite impossible with the means at the disposal of the workers to have gathered together and burned much of the stubble in the swampy parts before February, and even then a good deal would probably get pressed into the mud by the bullocks used for collecting it and for the subsequent ploughing. A very severe attack of ufra occurred in the treated fields, some of which gave practically no crop when harvested in November-December, 1916. In this case the treatment had not done the slightest good, but under the circumstances more could not have been expected. In 1917 the experiment was repeated under the supervision of the Agricultural Department, care being taken to postpone burning until the fields were dry enough to render it effective, which was not until February 21st. Two fields were treated and in both there were signs of ufra early in September. In one field about one-eighth of the crop was ultimately lost, in the other about one-fourth. For the first time for a number of years a paying harvest was obtained.

This last case introduces the main difficulty that is likely to be encountered in carrying out effective treatment of ufra. Throughout certain parts of the diseased tract low-lying patches of varying size are encountered in the middle of the paddy *bils*, which remain swampy well into January. In all of these which have had deep-water aman the stubble is left and usually gives a growth of small shoots and ears from December on until the ground dries, which may not be till late February. This only allows at most a month before the new crop is sown, as these low patches are always sown early, and not three months before the humidity rises enough to permit free infection. The second growth is liable to infection up to January in Dacca and into February in Noakhali. Before the ground is covered with water the worms have had only a short period in the dormant condition. They are then set free into the water in large numbers. Two months later the humidity is certainly high enough to permit migration and it is not unlikely that in these hollows, where the crop

becomes dense at an early period, the air within the crop approaches saturation sooner than elsewhere. It has been shown above that some worms can survive total immersion for at least 5 weeks even in the cold weather and for nearly 2 months if kept warm, so that by May we should expect a certain amount of active infection to be in progress in the crop. Probably the first infection is slight but all the conditions thenceforward are suitable for multiplication and migration. Thus we would expect to find the earlier attacks developing in these low-lying patches and spreading to the surrounding paddy, and this is exactly what the writer has been assured by cultivators in several places actually occurs. It is not suggested that all or the majority of the attacks originate from swampy patches. In the parts of Noakhali that the writer has visited, for instance, the attacks occur scattered through the paddy flats and often in different places in different years. But in the swampy, narrow, and deeply concave *bils* of the Madhupur Jungle the cultivators say that the infection often begins in the bottom patches year after year.

There seem to be only two ways in which these swampy patches can be dealt with, since there is little prospect of effectively burning the stubble in them. One is by drainage, and the other is by transforming them into boro paddy fields.

If they can be drained so as to dry out soon after harvest, no second growth is likely to come from the stubble and the latter can be removed and burned much earlier than is practicable at present. Thus they will be brought into conditions similar to those of fields where early burning and ploughing have proved effective in checking ufra.

The alternative is to deepen them so that they will hold standing water in which boro can be grown. This means abandoning the growth of deep-water aman in them, since aman cannot be grown after boro because the harvest of the latter is too late to permit of broadcasting aman. But this is no disadvantage, as boro is a more profitable crop than deep-water aman in most places. The difficulty is the water-supply. Standing water must be maintained in the boro fields until April, and this is only possible with irrigation, which is usually given about once a fortnight. Hence boro can only be grown, as already pointed out, along the banks of permanent channels, and if there is none near at hand where it is proposed to make swamp aman into boro land, one must be dug. The cost of this is considerable, but since these channels are the main means of communication (roads being useless where the country is submerged for half the year) the people are extraordinarily keen on getting new ones cut.

In certain parts of the Madhupur Jungle the people are already adopting the plan of cutting down and levelling the bottoms of the *bils* so as to transform them into boro fields, while the earth removed is used to raise the level of the margins high enough to grow *khama* paddy, which also escapes the disease. The extent to which this can be done by the unaided efforts of the cultivators is, however, limited, and the assistance of Government or of local authorities is required if it is to be carried out on a larger scale. It is probably one of the most useful ways in which local funds could be expended, as not only will communications be thereby improved but the produce of the land will be increased, apart altogether from ufra, because the varieties of paddy that can be grown on land thus treated are heavier yielders than the deep-water amans now found.

In the control of ufra it is evident that the methods must be largely directed to altering the conditions under which the rice crop is grown and so indirectly interfering with the activities of the parasite. The problem is more an agricultural than a pathological one. The pathologist can only aim at obtaining such a knowledge of the life-habits of the worm as to render it possible for the cultivator to arrange his practices so as to interfere as much as possible with its free development. There are not many places in India where the existing practices in rice-growing are so favourable to the peculiarly limited activities of *Tylenchus angustus* as those of the eastern districts of Bengal.

It is hoped that the results described above are sufficient to establish that much may be done to reduce the ravages of this pest. It has been conclusively proved that the destruction of the stubble of the winter rice will alone effect a great improvement. Where destruction is complete, or can be supplemented by a sufficient period of good cultivation of the soil before sowing the new crop, no worms will survive in those areas (and they are very large) in which the fields are dry enough to be taken in hand before the end of December. Where the fields remain moist into January and February it will still often be possible greatly to reduce the disease by burning at the right time and not attempting it before the stubble is dry enough to take fire. In the very muddy patches the growth of boro may be encouraged, and in many places a crop of transplanted aman taken after jute or (in some localities) after aus can with advantage replace the broadcasted aman. No one method will secure equally good results in all places, but each has its particular application and between them they cover a very high proportion of the fields subject to damage. But no one who has had any experience of the conditions of rice cultivation in Eastern Bengal, the enormous area concerned, the

lethargy of the cultivators, the difficulties of communications, and so on, can have any doubt but that progress will be slow and that it will be a labour of the greatest magnitude to effect a general improvement. The work all through has been hampered by the smallness of the trained staff available, and until this is remedied no adequate advance can be made.

Summary.

The work described above falls into three main divisions: A further study of the life-history and activities of the parasite, *Tylenchus angustus*, which causes the ufra disease of rice; an attempt to explain the anomalies in the behaviour of different classes of cultivated paddies to the disease, which were noticed in the earlier paper but which remained a complete puzzle until the close relation between atmospheric humidity and the movements of the worm on a dry surface was discovered; and finally the application of the facts ascertained to the control of the disease.

PUSA,

June 26, 1918.

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STUDIES IN INDIAN SUGARCANES, NO. 4.

TILLERING OR UNDERGROUND BRANCHING.

BY

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INTRODUCTION.

THE present research dates back to observations made in 1913, which showed that, in certain Punjab sugarcane varieties, there were differences in the canes growing in the same clump.[1] These were found to be early and late in origin, the former being thin and long, with short joints at the base, and the latter thicker and shorter and commencing with much longer joints. A certain number of dissections had been made of the underground, branching portion of cane seedlings and wild Saccharums, and it was decided to commence a systematic study of this part of the cane plant in the field, in order clearly to demonstrate the true relations of the differing canes in each clump. As additional points of interest, referred to below, presented themselves, the series was greatly extended, and during the past two years a very large number of cane stools have been carefully studied (*cf.* list on pp. 99 and 100).

For a proper understanding of the branching system of any plant, it is necessary to follow it from its earliest stages, and a study has accordingly

[1] Barber, C. A. Studies in Indian Sugarcanes, No. 1: Punjab canes, *Mem. Dep. Agri., Ind., Bot. Ser.*, Vol. VII, No. 1, May, 1915. This Memoir will in future be referred to as Mem. I. A second paper by the same author, Studies in Indian Sugarcanes, No. 2: Sugarcane seedlings, etc., Vol. VIII, No. 3, in the same series, will be referred to as Mem. II, while a third, Studies in Indian Sugarcanes, No. 3: Classification of Indian canes with special reference to Saretha and Sunnabile classes, will be referred to as Mem. III.

been made of the germination of the sugarcane seed and the sprouting of planted sets.

The important question of tillering soon connected itself with the dissection work, it being well known that, not only do the thick canes differ considerably in this respect among themselves, but, as a whole, they tiller much less freely than the indigenous Indian canes. Unfortunately there appear to be few accurate observations published on the tillering of Indian canes, and our own notes are far from complete. It is, however, hoped that the facts here presented will give a stimulus to this important side of crop investigation. Even in the tropical sugarcane countries, although a vast number of observations have from time to time been made, there are few papers dealing with the subject from a scientific point of view, and the great bulk of the notes made are not available for our purpose. Spacing, which has given rise to so many experiments in such crops as wheat and paddy, appears to have been occasionally tried in sugarcane; but the results are not easily obtainable, and no help can be got from those crops which are grown for the production of grain. A summary has been prepared of the literature of this part of the subject.

Attention was soon arrested by the fact, stated by various observers, that, during the lifetime of a cane plantation, a great many deaths occur, so that the number of shoots in early stages greatly exceeds that found at crop time. These observations have been made entirely with thick canes, and doubts arose in our mind as to whether they were equally applicable to Indian canes, as the deaths were by no means obvious in the plots. A series of shoot countings once a month was accordingly instituted to throw light on the question, but the results of these are not yet available for publication.

Incidentally, in the course of dissection, it was observed that different cane varieties showed considerable differences in their mode and degree of branching; and not only was this the case with individual varieties, but whole groups could without difficulty be distinguished from one another in this respect. The degree of branching in the Indian canes was seen, as a whole, to differ very considerably from that in thick canes, and this led to a study of that of wild Saccharums, when it was found, as expected, that the Indian canes stood half way between the wild species and the thick canes of the tropics. A further stimulus was thus added to the work, and it was attempted to discover, in the branching of the cane varieties, a means of tracing the origin of the cultivated canes from their wild ancestors, and, among the Indian canes, to select such as might be considered the more primitive,

and thus establish a connected series from the wild grasses to the thick canes of the tropics.

Lastly, differences were observed in the richness of the juice in the early and late canes of a plant, and these did not altogether tally with the views held regarding the richness of the thick and thin canes in tropical cane fields. The literature of the subject is punctuated by references to the relative richness in the juice of the "mother" cane and its branches, but, as no dissections seem to have been made, it is difficult to understand how the various observers distinguished these two classes of canes. There is obviously great confusion on the subject, for one observer, after stating his opinion, admitted that the mother shoot need not of necessity be the original main shoot of the clump but was the "thickest and best grown"! As will be seen, the result of our study is exactly the reverse, in that the main shoot is thinner and less well grown than its branches. This is indeed perfectly natural, when we consider the available equipment of leaves and roots in the young cane, as compared with that at the disposal of branches formed when the plant has grown up.

The dissection of the cane stool is a rather intricate and laborious piece of work. Upon taking it out of the ground, each clump is seen to be covered by a dense mass of tough roots, among which the soft buds are hidden, and these roots have all to be carefully cut away before the nature of the branching can be seen. The planting material with us consists of sets or pieces of cane on which there are at least three healthy buds, and these buds, usually all of them, develop into larger or smaller plants, which, however, are quite separate and only influence one another as regards the space available for their independent growth. It is usually impossible to make the dissection unless these plants are cut out and dealt with separately. In the list of dissections given on pages 99 and 100, the number of clumps and plants are therefore enumerated for each variety.

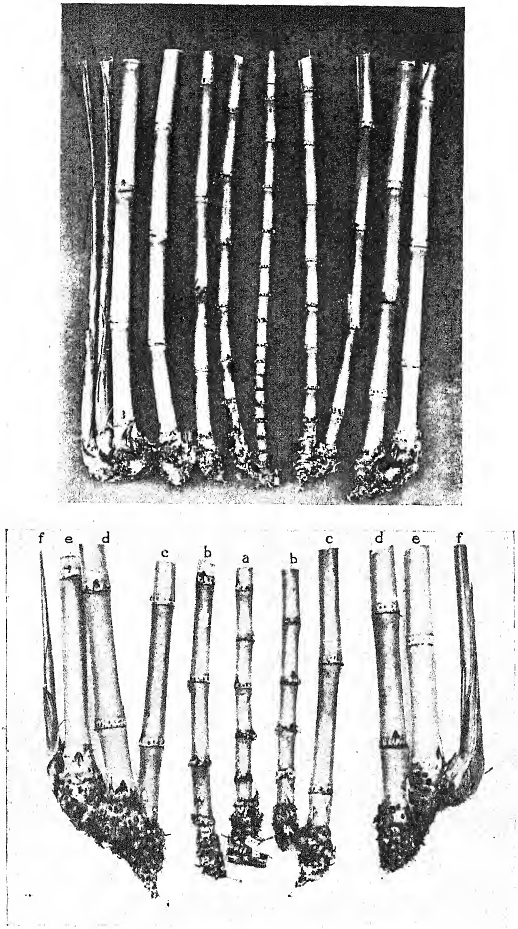
The main dissecting work was done in the 1916-17 and 1917-18 seasons, and in each year clumps were examined at two stages of growth for entirely different reasons. The first was at about four months, for the determination of the rate of cane formation; and the second at about eight months, for the study of the canes formed at crop time. It was soon found that, after this latter date, no new canes could be started in time to mature. In 1916-17, the dissections were largely concentrated on the Saretha and Sunnabile groups, which at that time had recently been separated and were being described. Six varieties of each of these groups were examined, and to them were added a few

from other groups and some thick canes and wild Saccharums. Altogether 51 clumps containing 133 plants were dissected during this season. The results of this work, briefly alluded to in Memoir III (pp. 156–160), were so suggestive and interesting that a fuller series was projected for the 1917-18 season. Six varieties of each of the five classes of Indian canes were chosen ; to these were added six from the unclassified list, six thick cane varieties, the four wild Saccharums growing on the farm and six Madras seedlings, all of which were grown from sets. Owing to the poor growth of the thick canes, a further set of 24 stools were examined at the sugarcane plantation at Nellikuppam, these being all of the *Red Mauritius* variety, which was known to grow very well there under crop conditions. During this season 239 clumps, consisting of 629 plants, were dissected. The facts observed during the previous year were utilized for the preparation of a definite scheme of observations and measurements, the main purpose of which was the comparison of the branching systems of the different groups and the characters of the branches of different orders. In each plant dissected a diagram was prepared, in which the relative position of the branches was shown, and a formula was prepared, in algebraical form, of the constitution of the plant as far as matured canes were concerned. Besides this, all the canes were measured as to thickness and length of joints, and notes on runners, curvatures, injuries, etc., were recorded. The present paper seeks to extract the general principles of the branching of the sugarcane plant from this mass of material.

The following are briefly the results of this study. From the four months' dissections it is seen that the different varieties vary greatly in the rate of maturing and cane-formation, but this study is complicated by the fact that it was impossible to examine all the stools at the same time owing to the large number dissected, the time occupied in the work extending over six weeks. A series of tables have been prepared, from which it is not difficult to judge of the relative rate of maturing of the different varieties (*cf.* pp. 129–132*a*).

From the general formulæ of canes at harvest, obtained by averaging the dissections of all the plants of a variety, it is seen that the branching in the various groups, from the wild Saccharums to the thick tropical canes, is of the same nature, but of very different degree (*cf.* p. 116). Taking a to represent the main shoot, b its branches, c branches of b, that is of the second order, and so on, we get a series of formulæ of the canes at crop time, varying from $a + \text{m}b + c$ in the thick canes, to $a + \text{m}b + \text{n}c + \text{n}d + \text{m}e + f$ in the wild Saccharums, and the different groups of Indian canes can be arranged in a series between these two extremes. It is hoped that a study of these formulæ

PLATE I.



Branches of different orders in the dissection of *Saccharum arundinaceum*, 112.
The main stem, a, is in the centre, and bs, cs, ds, es, and fs are arranged on each side, passing outwards from the middle.

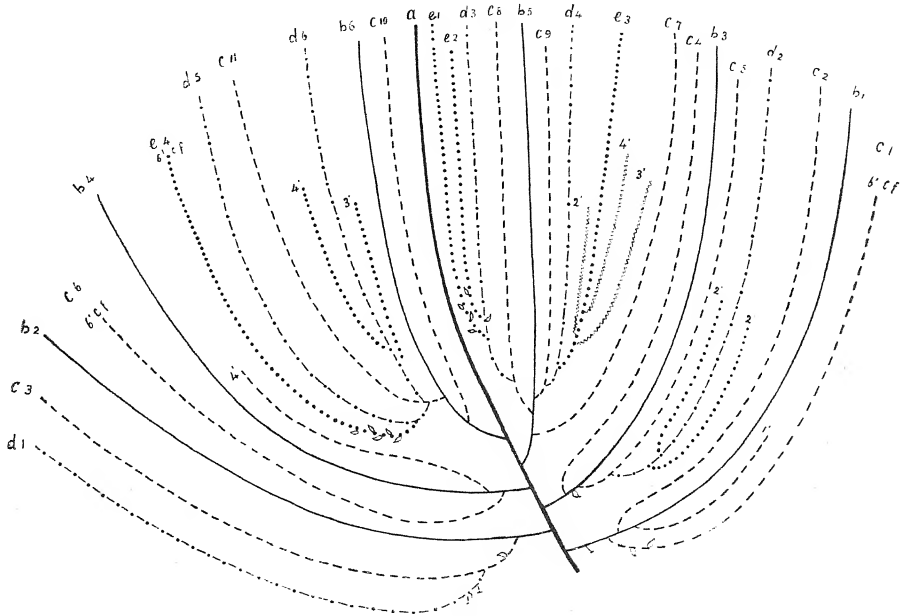


Diagram of the branching system in a plant of *Saccharum arundinaceum* (II2, of general list).

will throw some light on the stage of development of each group from its supposed wild ancestor.

The differences in form and size between the branches of different orders in the same plant have been carefully studied. Each cane has been measured as to the length of the basal, branching portion before it has assumed its full thickness, the thickness at two feet from the base, the average length of the joints in these two feet, the presence of curvature and runners, and so on. In all of these characters we find, as might have been expected, that there is a tardier development in the first shoot, and that this development increases in rapidity as the branches of the higher orders are reached. The general trend is for the branches of higher orders to be thicker, to have longer joints, and to show greater curvature. The main shoot has a longer basal, preparatory portion than its branches, but, when we pass to the other orders, the presence of basal curvatures, needed to place them in a position for upright growth, again increases the region of short joints at the base, for it is the general rule that a branch does not assume its full form until it is in a position to grow onward unimpeded. These details are all arranged in tabular form for the variety or group in the body of the Memoir (*cf.* Part III, Sections 4–6). In Memoir III, an example was given showing some of these characters, which was illustrated by plates. Here I add a more striking instance, namely, that of an ordinary plant of *Saccharum arundinaceum* (Pls. I and II), a species marked by its upright habit and symmetrical development, just as *Saccharum spontaneum* is by its intricate spreading growth. The diagram and detailed table of measurements are added, to give some idea of the character of the work done in each dissection undertaken. For further results, the reader is referred to the body of the work, as it is impossible adequately to summarize them without undue repetition.

The characters of the branches of different orders are seen to be so definite that, when a field is cut, we can without difficulty separate the canes at the mill into early and late. There is a good deal of similarity sometimes between the *a*s and *b*s, especially when the latter become facultative *a*s, but the change from *b*s to *c*s and *d*s is sufficiently striking to render their distinction generally very easy. This opens up a new line of work, in that it becomes possible to analyse these branches separately and to settle the question of their relative richness of juice and other qualities at the mill. Most of the work has, it is true, been conducted with Indian canes, and in one particular locality, but it seems unlikely that the thick canes will not fall into line, considering the general similarity of their branching system to that of Indian ones.

In the laborious work of dissection I desire to acknowledge my indebtedness to various members of my staff. At first all the dissections were done by myself, but I soon found that I was unable to cope with it, and interested my Assistant, M. R. Ry. T. S. Venkataraman, in the work and, later on, my second Botanical Assistant, M. R. Ry. U. Vittal Rao. With their help, I then trained two fieldmen, and the great mass of the later dissections were done by the latter under my personal supervision. In the first year, Fieldman G. V. James and, in the second, K. Rangaswami Pillai were engaged for months in the work, and I am greatly indebted to these officers for their care and intelligence. The selection in the field was entrusted to Fieldman R. Thomas, who had charge of rough cleaning and sending to the laboratory. The preparation of diagrams was mostly done by myself but, towards the end, here also I was able to leave it to Rangaswami Pillai. Several months were devoted to the work each year and, in 1917-18, it was found necessary to place three workers under the latter officer, who developed extraordinary neatness in his preparations. He was in entire charge of the work done on *Red Mauritius* canes at Nellikuppam. The shoot counting was under the direction of M. R. Ry. Venkataraman and chiefly done by R. Thomas and Plant Collector Abdul Sathar.

Measurements of Saccharum arundinaceum II 2, 1917-18.

(Extracted from the office files.)

NOTE. The development is fair, but not so mathematically arranged as in I 1.

Buds long, flat, hairy, scale like and not like the shooting buds of other varieties.

Formula. Canes at harvest : $a + 6b + 11c + 6d + 4e$.

Length of joints in the first 2′ and thickness at 2′ from the base. The first figure before the + is the length of the basal, preparatory portion of the cane, and consists of many short joints. (c, meaning curve, is inserted after the curve has finished.)

			Av. length of joint	Av. thickness in mm.
a	3¾, 1, 4½ + 1¼, 1¼, 1¼, 2, 2, 2½, 2½, 2¼, 3	...	2·0″	154
b^1	2 + 1½, 2½, 2½, 3¼, 3¾, 3¾, 3¾, 3¾ ...	...	3·1″	174
b^2	2¼ + 1½, 2¼, 3, 3½, 3½, 4, 4 ...	...	3·1″	170
b^3	2½ + 1¾, 2¼, 3, 3¼, 3¾, 3½, 3½ ...	...	3·0″	181
b^4	1¾ + 1, 2¼, 2¾, 2¾, 3½, 3½, 3½, 3½, 3	..	2·9″	174
b^5	3¼ + 1¾, 2, 2¼, 2½, 3, 3¼, 3, 3 ...	...	2·6″	179

	Av. length of joint	Av. thickness in mm.
b^6 2½ + 2½, 3, 3¼, 3¼, 3¼, 3, 3½	3·1″	196
c^1 4 + 2 (curving round under b^1), 6½, 7, 7½ ...	5·8″	242
c^2 1¾ + 4½ (straight from upper side of b^1), 6, 7, 8½	6·5″	192
c^3 2½ + 3½, 4¼, 6½, 5½	4·9″	208
c^4 2½ + 2½, sl. c 5½, 5½, 6½, 6¾	5·4″	226
c^5 2 + 1½, sl. c 6¼, 5¾, 6½, 5¾	5·2″	222
c^6 3 + 5½, 8, 8¼ under	7·3″	(207)
c^7 3½ curve + 3, 4, 5¼, 6¼, 6½	5·0″	180
c^8 2 sl. c + 2, 5, 5½, 4¾	5·1″	206
c^9 2¼ sl. c + 3½, 4, 4½, 4¼, 4¾	4·2″	196
c^{10} 2¾ + 1¼, 2½, 2¾, sl. c 3¼, 5, 4½, 5¾	3·6″	202
c^{11} 3 + 4½, 6, 5½, 5¾	5·3″	221
d^1 3¼ v. sl. c + 3, 7, 8½, 8½	6·8″	232
d^2 2¾ + 4½, 7, 8¼, 8	6·9″	247
d^3 2½ + 3¼, 5, 6¼, 6¾	5·3″	255
d^4 2 + 2¼, sl. c 3½, 4, 5¾, 6¼	4·4″	235
d^5 2¾ sl. c + 5, 6, 6, 7½	6·1″	221
d^6 3 + 4½, 6½, 6½, 7¾	6·3″	249
e^1 4½ (curving under c^2) + 3½, 6¼, 8, 8¼ ...	6·5″	223
e^2 3¼ sl. c + 5¼, 7¼, 7, 7¼	6·7″	232
e^3 3¼ curve + 5¼, 7¼, 7, 6½	6·5″	246
e^4 2 + 1¼, curve 5½, 7, 7½	5·3″	232

Summary of measurements of *Saccharum arundinaceum* II 2.

Formula of canes at harvest, $a + 6b + 11c + 6d + 4e$.

Shoots, $2c + 4e + 3f$. Burst buds, $1c + 3d + 2e + 9f$. Deaths, $1c + 1e$.

Average length of basal part, a* 3·7″, b 2·4″, c 2·7″, d 2·7″, e 3·2″.

Average length of joints in first 2′, a 2·0″, b 3·0″, c 5·3″, d 6·0″, e 6·2″.

Average thickness at 2′ (mm.), a 154, b 179, c 209, d 240, e 233.

Curving is absent in a and b, slight in c and d, moderately pronounced in e. There are no runners or injuries.

* The short-jointed, basal part is unusually long in a and consists of two sections, 3¾″ + 4½″ long, separated by one 1″ joint. The former figure only is taken here.

PART I. MORPHOLOGICAL CONSIDERATIONS.

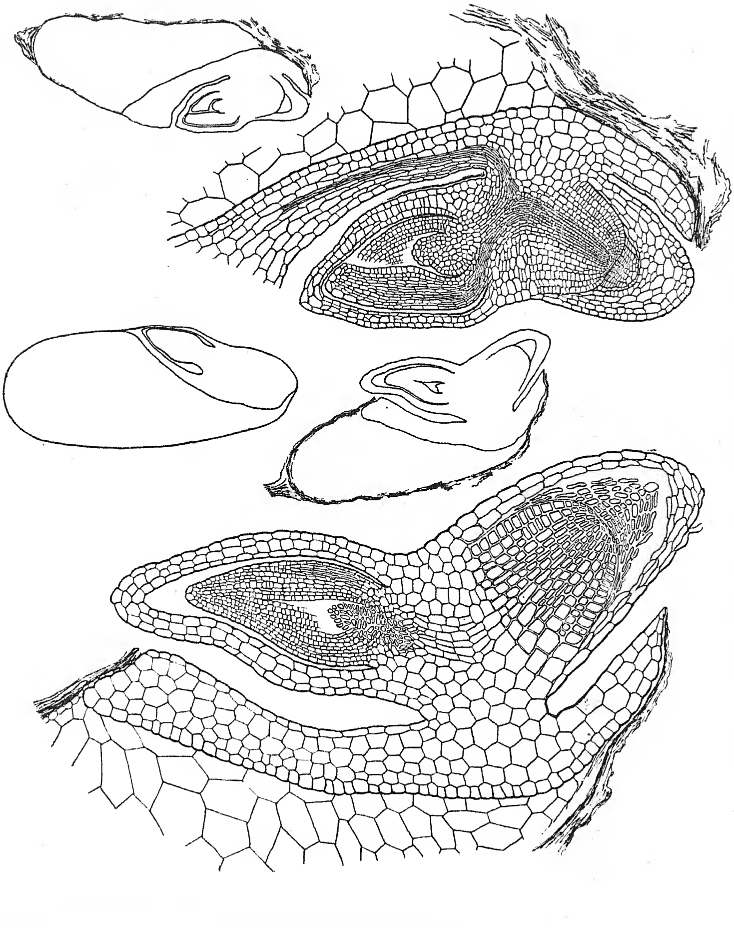
(1) Early stages of seedlings and sprouted cuttings.

Before proceeding to the description of branching in the sugarcane, it will be advisable to get some idea as to the various stages by which the plant, as we see it, is built up. For this purpose, I have put together observations and drawings, which have been made at different times during the past five years, on the germination of the cane seed and the sprouting of the sets, as these will form a useful basis for our study.

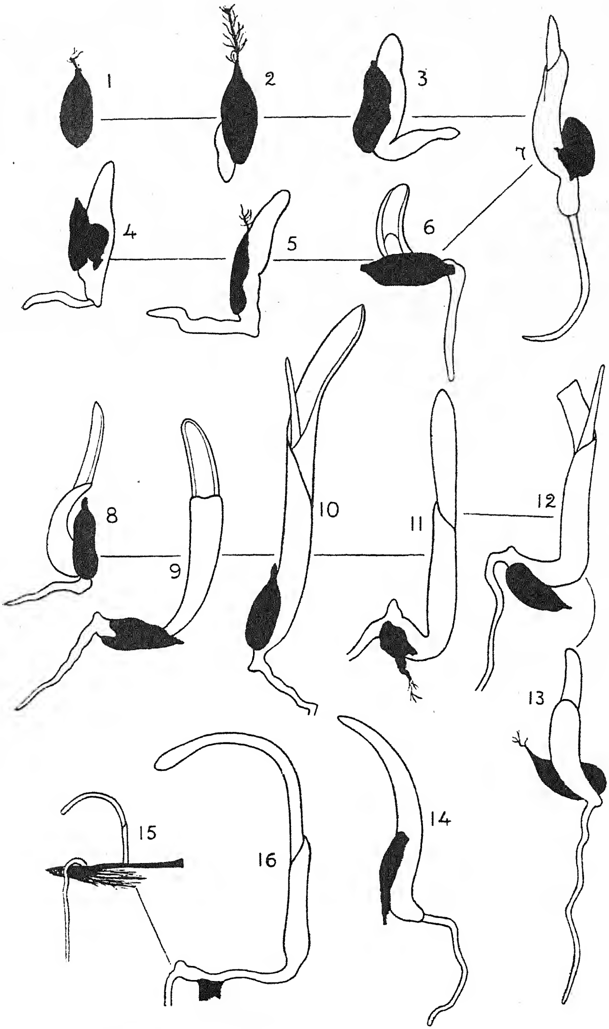
The seed of the sugarcane is extremely minute, the average length being 1·5 mm. and its breadth one-third of that amount. Strictly speaking, it is not merely a seed, but a fruit or caryopsis, for, as in all grasses, there is only one seed in the ovary, and its walls are fused with those of the fruit to an indistinguishable mass. The embryonic plant lies obliquely across one end of the seed, the rest being taken up by a mass of starch-bearing cells, the endosperm, a reserve of food for the early stages of growth. On comparing the relative sizes of germ and endosperm, the sugarcane appears to be poorly equipped with the latter, as, before the young plant protrudes from the seed-coats, it occupies in the vertical section nearly half of the space available. Considering the small size of the seed itself, there is thus very little food laid by for the initial stages of growth before it becomes independent; the cane seedling is excessively small and its growth is not nearly so rapid as the cultivated grains and, indeed, as the grass weeds which infest the seedling pans. The sugarcane in fact reminds us of the proverbial "mustard seed" in the smallness of its seed and the comparatively enormous size of the full grown plant. As a natural result of this, the seed of the sugarcane cannot be kept for long, although our series of observations, carried on for some years, show that its vitality is greater than previously supposed, and is not the same in all varieties (Mem. II, p. 127).

The general course of development may be gathered from the accompanying figures, firstly, of microtome sections through resting and germinating seeds (Pl. III), and, secondly, of drawings made from outside (Pls. IV, V and VI).

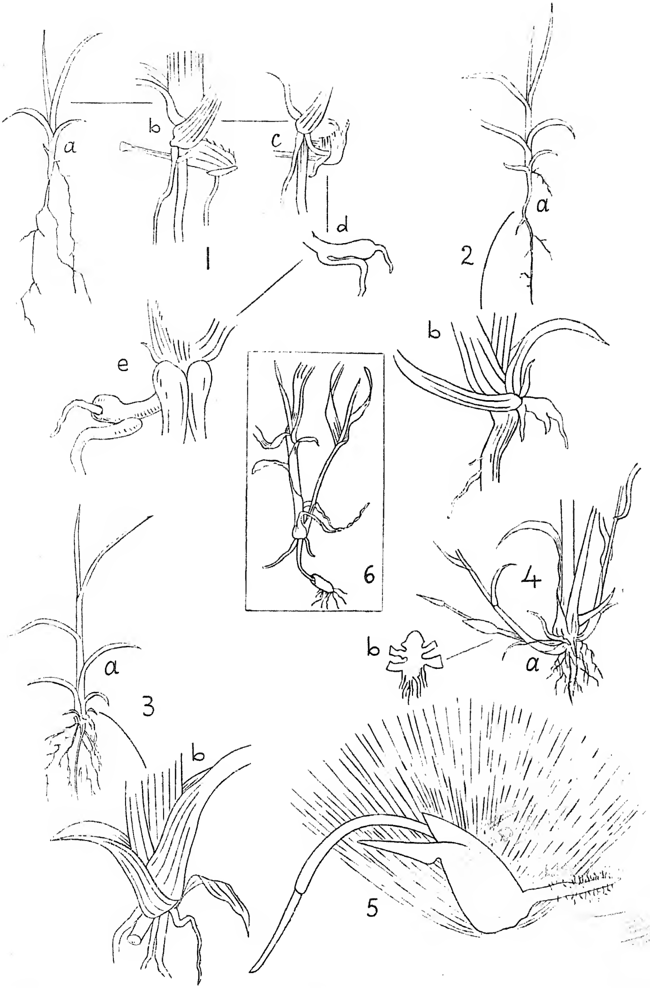
PLATE III.



Microtome sections through resting and germinating seeds of sugarcane. Madras Seedling No. 6.



Germinating seedlings of *Kassoer*, figs. 1-7, four days old; figs. 8-13, eight days old: *Louisiana Purple*, fig. 14, six days old: *Madras Seedling* No. 2, figs. 15 and 16, thirteen days old.



Young cane seedlings. Figs. 1-4, *Karun,* from one inch to one foot in heigt. Fig. 5, germinating grass seedling. Fig. 6, young barley plant (copied from Percival's *Agricultural Botany*).

There is little in these Plates which calls for special attention, as the general course agrees with that in grasses and has been sufficiently described in text books. In the cases of *Karun* seedlings which have been examined (Pl. V.), there is an elongation of the plumule axis below the first leaf, similar to that in the wheat, presumably designed to place the young plant clear of its seed-coats and near to the surface of the ground for the purpose of tillering, and I have reproduced a drawing from Percival's *Agricultural Botany* to make this clearer. But, in the *Karun* seedlings, a thickish root is given off from this elongated part of the stem, which I have not seen figured elsewhere. The purpose of this early root formation appears to be obvious enough, namely, to reinforce at the earliest possible moment the small amount of available stored material at the disposal of the young plant. The radicle with its first root has, as usual, a merely temporary existence, or lingers for some time as a minute fibre which can have little effect in aiding the plant in its growth. After this preliminary arrangement of the parts of the seedling has been concluded, the plumule develops its leaves in rapid succession and, near their bases, a series of thick adventitious roots are soon produced ; but the seed-coats, with the plug-like sucker, the elongated plumule axis and its first adventitious root, remain attached to the plant for a considerable time, as they have been detected in a *Karun* seedling already five inches above ground. Different stages in this development are given on Plates IV, V and VI.

The leaves are formed in one plane, alternately on either side of the stem, and the whole young plant may thus be pressed flat with all its parts spread out. At a very early stage of development, a bud is formed in the axil of each leaf, so that the branches, as well as the leaves, all arise in the same plane. The formation of successive leaves, one at a time, has the effect of dividing the stem into a series of segments, each provided with one leaf and one bud. These segments are usually termed joints, and it is the practice to regard the joint as bearing its leaf and bud at its lower end, being thus terminated above and below by a leaf, and, when this has withered and fallen, by the sharp ridge or leaf scar which completely surrounds the stem. The region where the joints are separated is termed the node or knot, as it is usually more or less swollen, and the joint as defined above thus becomes the internode. An appropriate arrangement of the fibrovascular bundles within the stem has meantime taken place, and this can be very well seen in longitudinal sections ; namely, while the bundles run parallel with the length of the stem in the internode, they form an intricate, wefted mass at the node, and branches are given off to the leaves and roots at this point. This arrangement of the bundles takes place very early in the development, and it is thus easier to demonstrate

the limits of the first formed joints by viewing them in a longitudinal section than from the outside (Pl. VIII, fig. 1 c). The region of root formation is at the base of each joint, above the origin of the leaf, and consists of a narrow ring of the surface where the nascent roots may be seen as two or three rows of dots ; this is termed the root zone. In parts of the stem beneath the level of the ground these root primordia quickly grow out and, perferating the leaf bases, form a mass of roots which, with their branchings and root hairs, leave no particle of soil untapped. The first formed joints are extremely short, being in the form of narrow superposed discs, and the leaves borne by them are therefore very close together. The joints are, moreover, extremely thin at first, but increase in thickness upwards, the successive leaves and roots providing material for their expansion, so that, as in many Monolcotyedons, a longitudinal section of the stem at the base shows its form to be that of an inverted cone (Pl. VI, fig. 1 d). The leaves, growing much more rapidly than the stem, increase in width at the base and encircle a larger portion of the circumference of the stem until their edges overlap. The further development of the plant proceeds on strictly similar lines. The main points to be held in view are the upward increase in thickness of the stem, the protrusion of the buds from the leaf axils, the increasing number and thickness of the roots developed on successive joints, the continual lengthening and widening of the leaves, so as not only to completely encircle the stem, but also to enclose the younger parts in a set of enveloping sheaths, and, later on, the gradual lengthening of successive joints, so that the growing point is raised above the surface of the ground. Immediately this occurs, the stimulus of moisture and darkness being removed, the formation of roots falls into abeyance, but the root eyes can be detected in the root zone from the outside throughout the length of the plant. The leaf, at first purely protective and consisting of leaf base or leaf sheath, on emerging to the light, soon develops a small green tip, the leaf blade or lamina, and this part rapidly increases in relative size until it forms the bulk of the leaf. But this leaf development is much more rapid than that of the stem, so that, when the growing point of the stem at length reaches the surface, the leaves have already reached a very respectable size (Pl. V). The largest seedling (fig. 4) has a leaf already a foot in length, whereas the stem is as yet only one-third of an inch long.

The cane seedling four or five months old, viewed from above ground, usually shows a tall central shoot surrounded at its base by a number of smaller shoots emerging from the soil near it. These are the developed buds of the lower leaf axils. As the first joints of the stem are very close together, and each has its lateral branch, these shoots, being pushed out of their original plane

from lack of room, appear all together as an irregular circle round the main shoot, but careful dissection shows that they all arise from different axils on alternate sides of the plant (Pl. VI). The growth of successive buds, however, varies a good deal, and their size at this stage bears no sort of relation to the time at which they were formed at the apex of the stem. Some buds remain quite small during the life of the plant, whereas others grow so rapidly that they soon overtake or even exceed the main shoot in length.

The branches pass through exactly the same stages as the parent stem, only differing from it in that they have a better start and take less time to develop into leafy shoots. They are thin at the place of origin, bear closely packed leaves on the short congested joints, have a bud in the axil of each leaf, and, as the leaves increase in length and expand their blades, the stems increase in thickness, the successive joints become longer and the shoots as a whole emerge from the ground. As in the main shoot, the leaves at first grow much faster than the stem and, for a long time, the actual growing points of the stems remain below the ground, the height of the plant being judged by the length of the expanded leaves. This is readily explained by the fact that the growth of each shoot is largely dependent on the feeding power of its own leaves and, until these are fairly large, no real progress can be made, hence their early protrusion and proportionately rapid early growth. The relative size of the main shoot and its branches, and the number of the latter vary much in the same batch of seedlings, all stages being observable between one strong cane, with or without a few small shoots at its base, and a bunch of shoots resembling a tuft of grass, in which it is difficult to distinguish between the main stem and its branches (*cf.* Pls. XVI and XXIV of Memoir II, for illustrations of this). The reason for this is not clear, for seedlings thus differing in their early stages are often not distinguishable in their degree of branching later on.

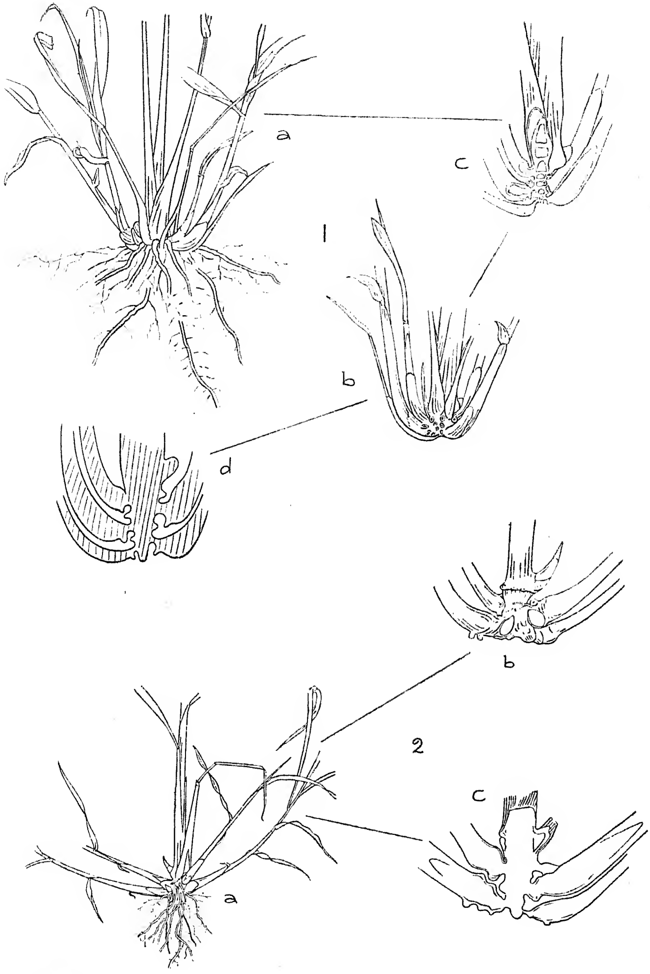
At a somewhat later stage, the lateral shoots, each as fully provided with buds as the parent stem, may also branch, giving rise to branches of the second degree, and this process may continue to several further degrees, this depending to a large extent on the parentage of the seedlings. Such shooting of the buds on lateral branches is not, however, usual until the plant has reached a further stage of development, unless, indeed, one of the branches receives an accidental injury low down, when its place is often taken by one of its uppermost buds. The chief points to bear in mind, concerning the branching of cane seedlings, are that every joint has its leaf and, protected by it, a bud, that both joint and bud have the power of forming independent roots if the necessity should arise, and that any of these buds may remain quiescent or

dormant throughout its life, or may shoot out at once or at a later stage in the growth of the plant as a whole. There is thus ample provision at hand for all the needs of the plant, whatever circumstances may arise. However severe the treatment above ground, there is a reserve of branches ready to be developed below, and, if one of the branches is either accidentally or purposely cut off, its place is taken by the emergence of one of its buds; and, if such a cut branch is placed in the ground, it is capable of sending out its roots under the stimulus of moisture and darkness, protruding its buds and developing into an independent plant.

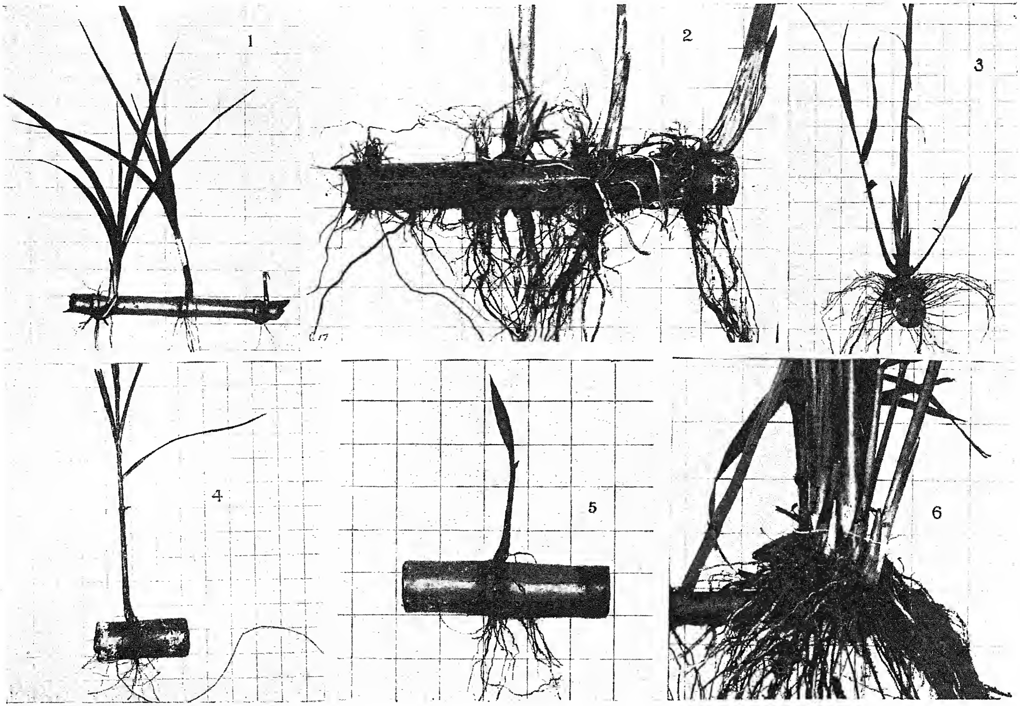
Advantage has been taken of these facts in the planting of the sugarcane in the field. Cultivated sugarcane is propagated from cut pieces of the stem and is always likely to be. Seedlings, although undoubtedly a much cheaper form of reproduction, do not inherit the good qualities of their parents uniformly, and many of them, even of the best parentage, are quite worthless from the sugar producing point of view. Although extremely easily reared in many cases, they require more individual attention than is justified under crop conditions, and they take longer to mature. While in South India, canes grown from cuttings take, on the average, twelve months to mature, seedlings only become full grown when they are about eighteen months old. Besides this, there are many good kinds which do not produce seed at all, either because of infertility or the total absence of flowering. In vegetative reproduction the good qualities of the variety are rigidly handed down from generation to generation, although there appears to be a gradual diminution in vigour as the years pass.

The vegetative method of reproduction is rendered easy, as explained above, in that each joint is furnished with its bud and a number of root primordia, and both of these require little stimulus to grow out. The condition of the bud may be compared with that of the germ in the seed, in that it is placed in immediate connection with a mass of readily assimilable nutriment in the joint to which it belongs. It is, however, much more fully developed than the germ, and it takes little time, under suitable conditions of moisture and warmth, for it to produce a mass of roots and leaves. The development of this bud need not detain us here. It is practically identical with that of the shoots described above, being merely a branch of the plant of a higher order. A series of stages are shown in Plates VII and VIII.

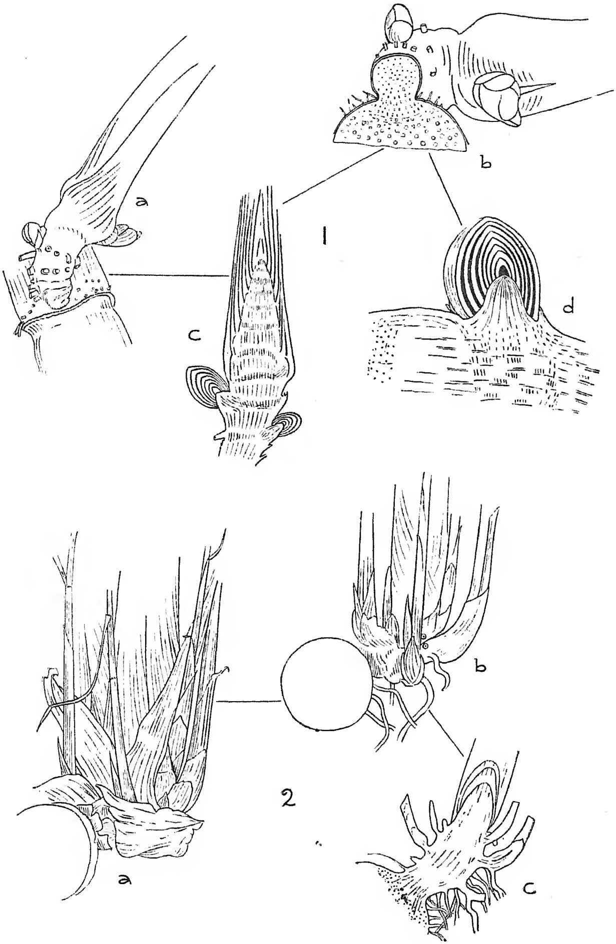
In planting, the whole cane is sometimes laid in a furrow, lightly covered with earth and watered; in many places, only the upper, immature parts of the cane are used and these, called "tops," are placed slanting in the ground;



Cane seedlings about four months old. Fig. 1, *Poovan* seedling dissected (113 days old). Fig. 2, Seedling of *Saccharum spontaneum* (133 days old).



Sprouting set plants. Fig .1, *Saccharum arundinaceum*, showingbud beneath the set curving upwards and forming a healthy shoot. Fig. 2. *Gillman*, 25 days old. Fig. 3, *Red Mauritius*, 37 days old. Figs. 4 and 5, *Vellai*, 37 days old. Fig. 6, *Chin*, 50 days old.



Dissections of sprouting set plants. Fig. 1, *Gillman*, one month old. Fig. 2, *Red Mauritius*, two months old.

but in India, as a rule, the whole cane is cut up into pieces called "sets," each of which has a definite number of joints with healthy living buds. Almost all canes germinate readily from sets, and, in India, they seem to produce healthier and stronger plants than the tops; but cases have been met with, as in *Seema* of the Godavari District, where sets are generally infertile and tops have to be used.[1] The sets in South India usually contain three joints; germination takes place more rapidly than in North India, and, if the field has not sprouted within a week or ten days, it is customary to plant again. In North India the climate at the time of planting is very cold and, not infrequently, a month elapses before the shoots appear above ground.

When, in a warm climate, the sets are placed horizontally in shallow trenches and watered, they at once send forth roots and the buds burst. Although, possibly, in ideal planting, it would be best to place the sets so that the bud plane lies parallel with the surface, this is not generally attended to nor essential, for the shoots are negatively geotropic and quickly find their way round the set to the surface of the ground.[2] The root eyes protrude and form a circlet of fibres round the set, those beneath growing much more strongly than those facing upwards, and these roots supply the stream of water which washes the nutriment stored in the joint to the developing bud. But very soon the lower joints of the new shoot form their own roots—thicker, whiter, and longer. When this occurs the shoot forms a new, independent plant, and the decayed joint from which it has arisen is left behind much as the cast off seed-coats in a germinated seedling. Connection with the plants developed from the other buds in the same set is thus entirely severed. Lateral branching takes place very early in the young plant, and these branches also produce their own roots, and, in a couple of months, the set plant has attained to the size and form of the six months seedling, and is growing much more rapidly.

The canes of different ages in the same clump are sometimes very different. This has been already noted in the remarks on early and late canes. But this difference is much greater in seedlings than in canes grown from cuttings.

[1] Barber, C. A. Scientific Report of the Samalkota Agricultural Station for the year ending 31st March, 1906. *Bulletin of Madras Agricultural Department*, 1907, p. 24.

[2] Since writing the above our attention has been drawn to the following. Kulkarni, in Dharwar, has made a series of experiments in planting sets, each with one bud only, and the set placed so that this bud is upward. He only allowed the mother shoot to grow and its branches were carefully removed. He claims that, by this means, sprouting takes place one week earlier, all the canes ripen together and a larger number are obtained per acre. (Kulkarni, M. L. Experiments in planting sugarcane sets with single eye-buds, etc. *Agr. Jnl., Ind.*, Special Science Congress Number, 1918.)

See also p. 102 and Plate VII, fig. 1 of this Memoir.

It is true that all the canes seem to be similar in some cases, but in others it is not unusual to note thin, yellow, sprawling canes developed first, these succeeded by reddish tinged slanting canes, while the latest formed are thick and dark purple ; and all sorts of such colour variations may be detected. as well as variations in thickness and erectness. We do not as yet know whether this variability is handed on to the next generation, when the seedling is grown vegetatively, or whether only one of the forms of cane noted is characteristic of the future crop cane, but experiments are being conducted to determine this point, which is of considerable moment for the proper selection of seedlings.

(2) Periods of growth.

The great bulk of the Order Gramineæ consists of grasses, and it will be of interest briefly to consider their mode of branching, in order to see in what respects the sugarcane resembles them—for the sugarcane has often been described as a gigantic grass. There are two well marked phases of development in grasses, the first, in which the plant remains low and adds shoot to shoot until a dense bush is formed, in which the shoots are often inextricably intertwined and point in all directions; and, the second, in which the ends of certain of these branches become erect, rapidly increase in length and proceed to form the spikes of flowers and ears of grain. In the first stage the energy of the plant is devoted to multiplying its number of shoots, chiefly by the branching of the underground portion; in the second, branching ceases and the energy is diverted to pushing the branches high into the air and the formation of flowers where they can be readily fertilized, and seed where it can be scattered abroad.

In the sugarcane this division into periods of growth is to a certain extent hidden, in that, both in seedlings and set plants, each shoot, as soon as it is formed, pushes into the air and grows steadily upwards to form the aerial stem or cane. Flowering is a matter of secondary importance, and has largely fallen into desuetude from long propagation by the vegetative method. This is especially so in North India, where flowering is rare, but, in the Peninsula, as in most tropical countries, flowering takes place regularly towards the close of the growing season, and the fields then present a mass of feathery plumes over the whole area (*cf.* Pl. V, Memoir II). It may be noted, in passing, that the time of flowering does not coincide with that of reaping the crop, as these two periods are induced by very different climatic conditions. Flowering occurs at Coimbatore during the period of greatest rainfall in October and

November, and indeed seems to be greatly influenced in its profusion by the amount of rain falling during the year, while the cane is harvested when the juice is richest, and this occurs in February and March, after the cold season, when the air becomes hot and dry.

The formation of new shoots at the base of the cane plant proceeds during the whole of the growing period, but there is no doubt that it is much more active at the commencement of growth, for the rapid formation of canes is not really taken up until the plant is six or seven months old (*cf* p. 108). And this separation of the branching and lengthening periods of the plant is in certain cases emphasized by local conditions of growth. In South India the sets are planted at the commencement of the hot, dry weather, when the harvest is reaped, sugarcane being everywhere an irrigated crop. In the Godavari District, the young plants, after growing for a few months, receive a severe check, in that the irrigation channels are closed every year in May for cleaning, and, for some six weeks, irrigation is in abeyance, and the plants depend on such scanty showers as fall at this time. During this period, the branching of the underground parts goes on steadily, although little is added to the height of the plants. In fact the plants often appear to grow shorter, in that they are attacked by shoot-borer and many of the shoots are destroyed. But the ryot views the matter with equanimity, because he knows that this pest merely causes the lateral branches to be developed in larger numbers, and he asserts that he gets a better stand of canes when there is an attack of moth borer. It is probably of no great disadvantage for the shoots to be checked when there is no water to continue their growth; but cases are also met with where whole fields are destroyed by the pest, or ugly gaps are seen in the plantations. The branching period is lengthened and made more pronounced in this case which, in some respects, is analogous to winter-sown wheat in Europe.

A similar lengthening of the branching period is to be noted as the result of certain diseases of the cane. In the neighbourhood of Coimbatore, where many of the wells contain brackish water, sometimes the plants, especially ratoons, never reach the cane-forming period, but continue throughout the season to develop new shoots with narrow leaves, which do not grow in length but branch again, until, at crop time, nothing is seen but a number of low, dense, grassy bushes. A case was met with by the author on new, rough land, near the emergence of the Amravati river from the hills, where, in a couple of acres fourteen months old, only a few canes were observable, and the field closely resembled one of *Guinea grass*. It is needless to point out the similarity of this growth to that induced by *sereh* in Java and certain diseased

clumps observed years ago in Barbados, where all the buds and roots of the short canes shoot out, till a dense mass of grassy leaves is produced in place of a few tall healthy canes. (For an example of this kind of growth, see Pl. XII, fig. 1.)

Another feature in the branching of grasses may be noted here. It is usual to divide them, according to their mode of growth, into tufted grasses and sod-formers. In the latter, underground branching assumes an intense form, each bud piercing the base of its enveloping leaf sheath, and again branching itself, until, with the masses of roots formed at the bases of the joints, the soil is permeated so thoroughly that it can be cut into coherent slabs, as in lawns and permanent pastures. The individual plants are closely interlocked and it becomes very difficult to dissect them out without injury. The main feature in these grasses is the great development of underground runners or stolons, the ends of which emerge and bear tufts of leaves for the purpose of nutrition, while their place is taken by buds near the upward bend, and the underground part is thus formed of a mass of sympodia. Flowering takes place at a certain season, but this does not interfere with the underground branching. In the tufted grasses, on the other hand, after a limited period of underground branching, a number of erect shoots are formed which in due course proceed to the formation of flowers and grain. The buds in this case do not pierce the bases of the enclosing leaf sheaths, but grow up inside them, emerging where the sheath joins the lamina, only splitting the leaf sheath by their increase in thickness. The individual plants are easily separable, do not interlock, and each forms a more or less distinct tuft (*cf.* Percival, *Agricultural Botany*).

It is at once obvious that the sugarcane belongs to the latter class, as do the usual cultivated cereals. This also applies to the wild Saccharums, *Munja, Narenga, arundinaceum* and *spontaneum*, grown on the Cane-breeding Station. The two former are typical tufted grasses, no cane is formed and the flowering shoots are ephemeral structures, drying up after the seed is ripened. In *Saccharum arundinaceum* and *Saccharum spontaneum*, solid canes are formed. *Saccharum spontaneum*, although undoubtedly a tufted form, produces long underground shoots which emerge at intervals and thus spread the plant over a considerable area. It is difficult in growing this species, either from seed or from sets, to confine it to its bed, and the neighbouring paths are soon invaded. We may thus imagine an approach to the sod-former here. The nearest approach to sod-formation in *Saccharum spontaneum* which we have observed is on the banks of the Irrawaddy, where sandbanks are protected from being washed away by an interlacing mass of roots and runners, which forms a

solid cap a foot in thickness. The formation of underground runners is occasionally met with in cultivated canes. It is commonest in the Saretha group, the most primitive class of indigenous Indian canes, and, apparently, the nearest in descent to the wild *Saccharum spontaneum*. In other classes, runners are usually only formed where space is needed for the free development of a large number of cane stems. Thus we meet with them most frequently in the Mungo and Pansahi groups which are characterized by much branching. In these cases long, thin joints are intercalated between the normal short thick ones of commencing shoots, and in the dissections these are always noted (*cf.* also pp. 104 and 112).

(3) THE BRANCHING OF THE CANE ABOVE GROUND AND ABNORMAL BUD FORMATION.

Branching of the cane plant below ground is a well marked feature in all varieties. Above ground, in the light and in the absence of the stimulus of moisture, the buds usually remain inactive during the period of maximum growth. But the shooting of aerial buds is by no means uncommon, and is of some disadvantage from the crop point of view. It has been noted that some varieties, such, for instance, as *B. 208*, shoot more readily than others; but there are a number of circumstances which render all canes more or less liable to this defect. Any injury to a growing cane will tend to cause the buds below the injured place to shoot out because of the damming up of the current of water and nutrition. This is often seen where stem borer is at work. The joints immediately above the attack are shorter and thinner than the average, and large shoots are often observed coming from the nodes below the borer hole. Canes which have lodged or fallen will frequently develop a mass of shoots all along the prostrate part; over-ripe canes and such as have flowered usually form a mass of shoots in the upper part if allowed to continue growing; lastly, the local climate has a very distinct influence in the matter. Thus, when the same canes are grown at Pusa and at Coimbatore, they behave very differently as regards shooting. At Coimbatore, which is in a semi-arid region, shooting of the canes is very rare; while at Pusa, with its abundant supply of subsoil water, approaching the surface in the rains, a great mass of green is sometimes seen all the way up the stem, even in erect canes, long before the reaping season. This shooting of the buds is generally correlated with a more or less active protrusion of the root eyes. In places where there is a marked difference in the humidity and temperature at different periods of the cane's growth, this difference is often permanently marked on the different joints of the cane stem. Thus, at Rajshahi in North Bengal, it is easy at

crop time, to determine what joints had been formed during the hot, dry summer months, and at what stages the rains attained their maximum and ceased to flood the ground. The rooting and shooting of the canes in damp climates is often avoided by trashing, or pulling off the adherent but dying leaves, and it would be worth while considering the desirability of trashing canes in North India during the rains, in places where these defects are most marked.

Besides the normal branching of the cane, due to the protrusion of the ordinary buds on the joints, cases of abnormality are not infrequently met with, caused by irregularity in the bud development. Here and there canes have been met with where the joints have been altogether devoid of buds, and *Kaghze* has been marked in the Coimbatore collection as especially liable to this deformity. Here obviously no branching can take place. In others, double or triple buds have been met with in place of the single bud, and in the usual position. Where double buds occur, they are not infrequently the prelude to a dichotomous splitting of the cane into two equal halves, each then proceeding to grow normally. On passing down the stem, such double buds are seen to be preceded by buds of abnormal width, accompanied by a flattening of the stem (Pl. IX). Such cases have been very clearly described by Jeswiet,[1] and need not be further dealt with here. Among the cases of triple buds, one was noted as being extremely regular in its development, and it was preserved because of its interesting nature. After four years of reproduction the same abnormality can be seen, showing that it is a heredit-able character of the seedling when propagated by cuttings.

But the most striking and frequent case of abnormal bud formation is when they are irregularly produced in different parts of the stem without any regard to the usual position. They are often met with in the root zone, for here there is, more or less permanently, meristematic tissue, but they may also appear at almost any part of the joint. They may arise direct from the outer layers of the stem, but more usually they are preceded by the formation of an irregular mass of callus, over which the buds are distributed unevenly, varying from mere pin points of tissue to fully formed buds with scaly leaves. Curious monstrous forms are thus produced, some of which have been selected for illustration on Plates X and XI. They would appear to be commoner on seedlings of certain parentage, although they have been found sporadically

[1] Jeswiet, J. Beschrijving der soorten van het suikerriet. Erste bijlage. Morphologie van het suikerriet. *Archief v. d. Suikerind. in Ned. Ind.*, Maart, 1916.

Explanation of Plate IX.

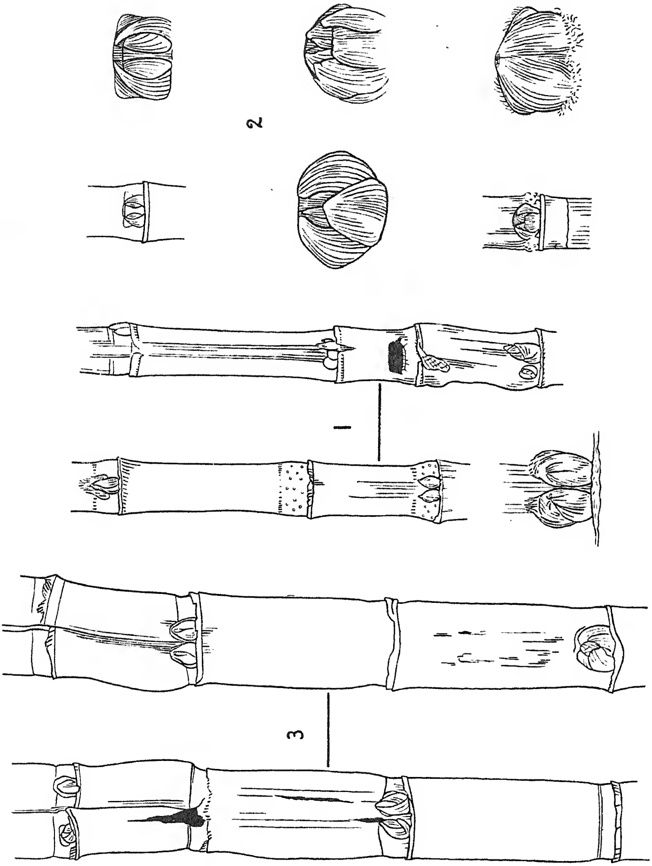
Doubling of buds and branching of the cane.

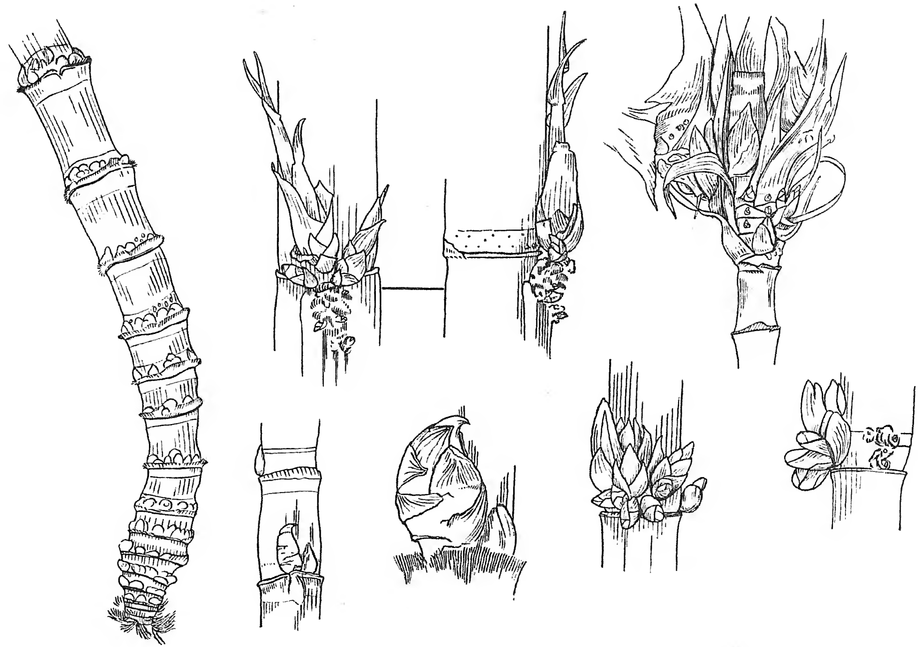
Fig. 1. Doubling of buds. In one case there is a well marked "cut."

„ 2. Incipient doubling, shown by broadening of the buds and duplication of some of the bracts.

„ 3. A case of dichotomous branching. A drawing has been made of each side of the same piece of cane. The buds of the two branches are preceded, below, by a broad one, showing incipient doubling.

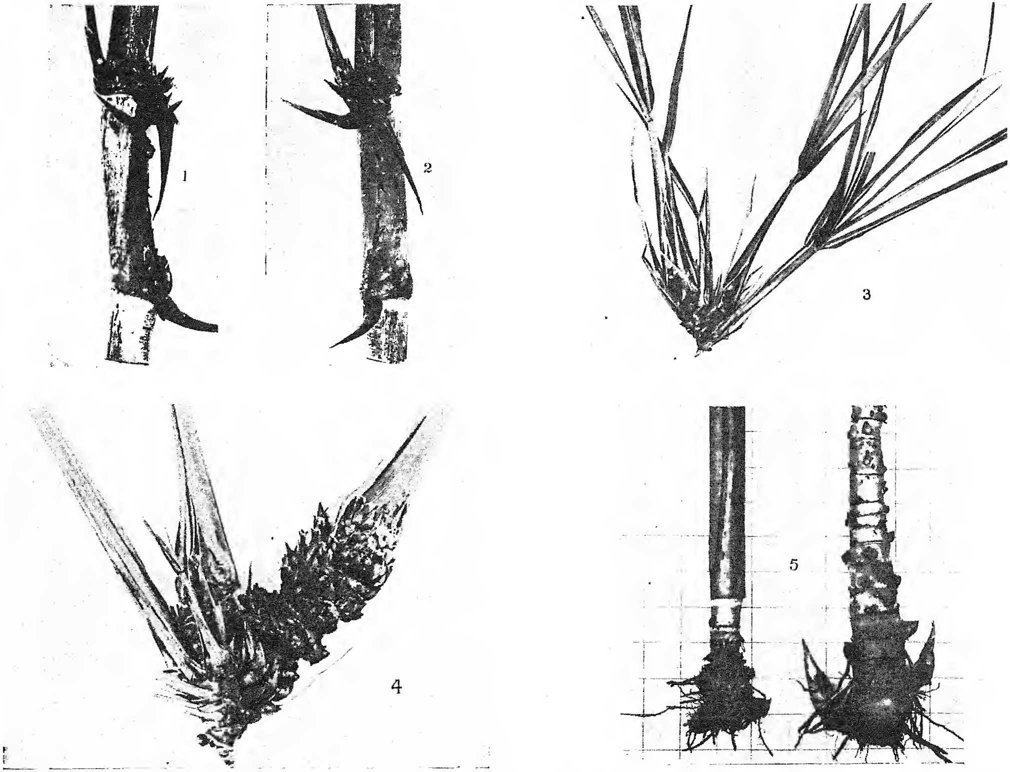
PLATE IX





Callus-formed buds and shoots. The multiplication of buds is usually confined to the root zone, but, in one case, a callus mass is spreading downwards from this region, and is developing buds at intervals.

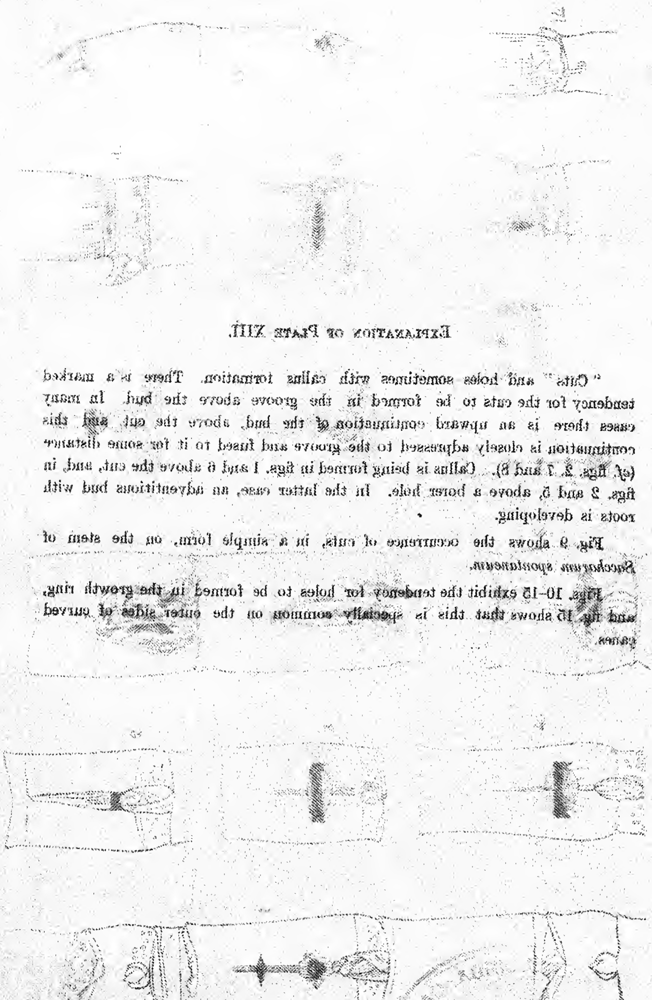
PLATE XI.



Photographs of callus-formed buds and shoots.

PLATE XII.

Fig. 1, Grass-like cane plant, caused by abnormal shooting of all the buds. This is similar in form to plants attacked by various diseases, including *Sereh*.
Fig. 2, Canes suffering from " cuts ".

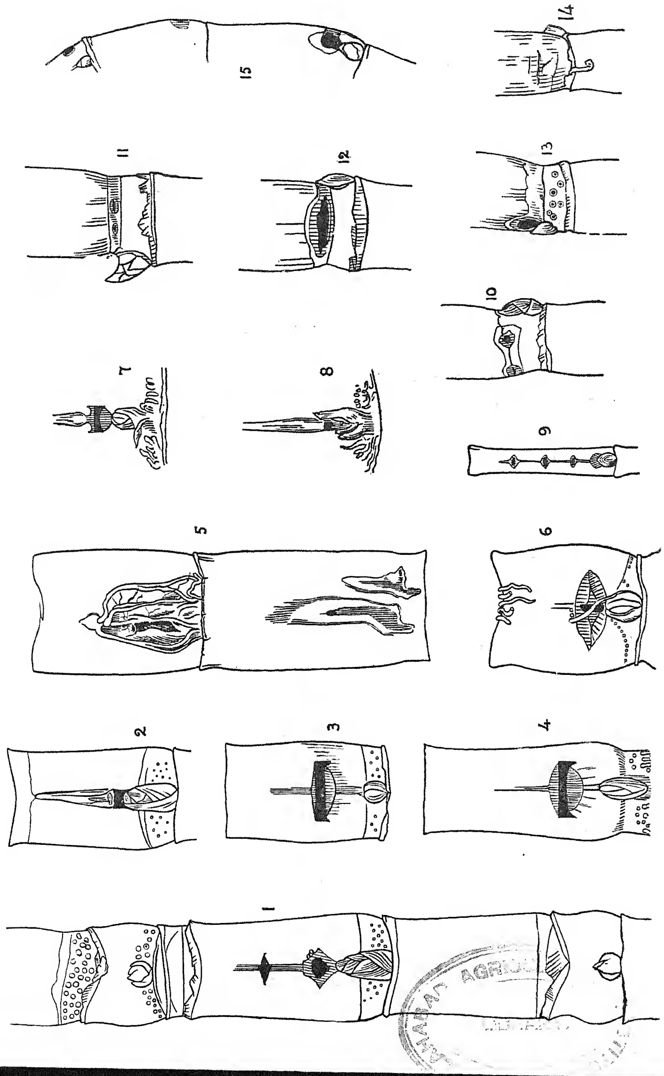


Explanation of Plate XIII.

"Cuts" and holes sometimes with callus formation. There is a marked tendency for the cuts to be formed in the groove above the bud. In many cases there is an upward continuation of the bud, above the cut, and this continuation is closely adpressed to the groove and fused to it for some distance (*cf.* figs. 2, 7 and 8). Callus is being formed in figs. 1 and 6 above the cut, and, in figs. 2 and 5, above a borer hole. In the latter case, an adventitious bud with roots is developing.

Fig. 9 shows the occurrence of cuts, in a simple form, on the stem of *Saccharum spontaneum.*

Figs. 10–15 exhibit the tendency for holes to be formed in the growth ring, and fig. 15 shows that this is specially common on the outer sides of curved canes.



in almost all the plots, thus conveying the suggestion that the formation of cane plants from seed is no longer governed by the strict rules applicable to seed-bearing plants. In 1917-18 the *Khelia* plot of seedlings was thus marked out as containing numerous examples of this deformity. The cases thus far mentioned do not seem to have their origin in any injury to the cane tissues, but, in other cases, the callus results from the hole of a stem borer, the breaking of a cane, or the curious " cuts " above the bud in the groove, to which attention was drawn in the *Journal of Heredity* of February 1916. These cuts have been found in many of our seedlings and cane varieties on the farm, and appear not to be the result of any insect or other attack, but on differences in tension of the superficial layers of the stem. They have been found also in seedlings of *Saccharum spontaneum* in some quantity, and various cases have been drawn at intervals during the past five years. Some of these may be seen on Plates XII and XIII. A large number of other abnormalities have been noted in the seedlings and varieties grown on the station, and the study of these would undoubtedly prove of interest from the morphological point of view.

PART II. TILLERING.

(1) In seedlings.

The tillering or branching of the cane differs considerably according to the variety, and, as the ultimate crop of canes produced is obviously influenced by this character, it is of some importance. Scattered through the literature of the sugarcane, there are to be found many countings of shoots at various stages of growth, as well as the numbers of canes reaped at harvest, and among the records on estates a far greater number probably exist. From these observations the tillering powers of the various canes under cultivation in different circumstances have been fairly accurately determined. But, when we attempt to draw conclusions from this material, we see that the subject has rarely been treated from a scientific point of view, and in almost every case there is an absence of the careful consideration of external factors which might be expected to have influence. We still wait for an exhaustive treatment of the subject with scientific safeguards. The present paper may be regarded as, in some sort, preparatory to such work being undertaken.

It will be well, in the first place, to consider exactly what the term implies. *Tiller* is an old English word allied to the *telgor* of the Anglo-Saxon, meaning a plant or shoot, and akin to the Dutch *telen*, to breed. At present it is, properly speaking, confined to the mode of branching characteristic of grasses. This consists in the multiplication of shoots, in the young plants, from the lower, short jointed portion of the stem, immediately below the surface of the ground. As we have noted elsewhere, this branching is the main work of the plant during its earlier period of growth. If the seed is sown too deep, one or more elongated internodes bring it to the surface, and then the joints become short and congested and branching commences (Pl. V, fig. 6). Shoots are not only given off by the main stem, but its branches may in their turn give off shoots, until a large number are produced. Branching in the upper, aerial part of the plant is less developed, occurs at a later period of growth and has nothing to do with tillering (*cf.* Percival, *Agricultural Botany*, where the matter is somewhat fully dealt with).

The factors influencing the amount of tillering in any plant are both inherent and external. Different species and varieties, as well as the seedlings raised in batches from the same parents, differ enormously in this character ;

but this difference is often cloaked by a number of surrounding circumstances, all of which seem to be translatable into the amount of food available, and of these, space, light, water, soil, and manure appear to be the most important.

We have followed the early stages of the sugarcane seedling somewhat carefully in a previous section, and it is at once evident that this mode of branching is present in it, and, therefore, that true tillering occurs in the sugarcane. We usually judge of the vigour of the cane seedlings grown at the Cane-breeding Station, by counting the numbers of canes and shoots at harvest time, and we thus have a certain amount of information as to the tillering capacity of the progeny of different parents, and the accompanying table gives a summary of these details. While examining the figures in this table, it will be well to note the spacing and rainfall for each year:

1911–13. Botanic Garden: plants 6′ apart, in pits measuring 3′ each way, filled with soil and manure: 1,200 per acre: rainfall 31·23.″

1912–14. Cane-breeding Station: fields 7, 8 and 9, sandy loam, but insufficiently prepared: 6′ apart, in pits measuring 2′ each way: 1,200 per acre: rainfall 21·08″. In this and the following cases the pits or trenches filled with prepared soil.

1913–15. Fields 10 and 11, clayey loam: 5′ apart, in pits measuring 2′ each way: 1,740 per acre: rainfall 36·49″: canes counted at 14 months.

1914–16. Fields 15 and 16 and parts of 12 and 13, clayey loam: $4\frac{1}{2}' \times 5\frac{1}{2}'$ apart, in pits measuring $1\frac{1}{2}'$ each way: 1,740 per acre: rainfall 23·03″.

1915–17. Fields 17–20, clayey loam: planted in trenches $1' \times 1\frac{1}{2}'$, the plants $4' \times 5'$ apart: 1,921 per acre: rainfall 24·97″.

1916–18. Fields 10 and 11, clayey loam: trenches $1' \times 1\frac{1}{2}'$, the plants $4' \times 2\frac{3}{4}'$ apart: 3,760 per acre: rainfall 19·31″.

The 1911–13 plants were treated exceptionally well in their large pits of prepared earth, and the rainfall was good: the pits were smaller for the 1912-14 seedlings and the rainfall was meagre: the 1913–15 plants had the benefit of heavy, well distributed rain, but the rainfall for the 1914–16 plants was again meagre: in 1915-17 there was fair rain and the plants were 1,921 to the acre; but in 1916–18 a marked drought occurred and the plants were nearly twice as close together. Taking the size of the pits or trenches filled with prepared earth together with the spacing, we see a continual narrowing of the limits of good soil in successive years. The rainfall was excessive in 1911-13 and 1913–15, extremely meagre in 1912–14 and 1916–18. In 1913–15 the cane counting was done later than usual.

Tillering of seedlings in successive years in the Cane-breeding Station.

Parentage	Seedling year	Number of lots	Number of seedlings	Average number of canes per seedling	Variations in averages of different lots	REMARKS
Thick canes ...	1912-14	4	862	14·5	One (13 plants) 11, the rest 13-15	
	1913-15	10	846	15·2	One (47) 26, the rest 13-16	The *Karun* lot (47 plants) showed unusual tillering and no explanation is recorded
	1914-16	4	963	14 6	One (241) 12, the rest 15-16	
	1915-17	9	521	13 5	One (72) 9, the rest 12-17	*Mauritius 55* seedlings (72) averaged 9 canes, *Naga B* (54) averaged 17
	1916-18	1	50	10·0	......	*J. 247*, a good tillering variety
Rogues among thick cane seedlings	1911-13	3	11	69·2	40-92	*Poovan, Namam, Kaludai Boothan*
	1912-14	2	2	97·5	55-140	*Karun* 55, *B. 208* 140
	1913-15	2	3	88·3	45-110	*Karun* 110, *B. 208* 45
	1914-16	2	17	56·1	56-69	*Ashy* and *Striped Mauritius*
	1915-17	6	11	46 6	18-85	
	1916-18	7	8	30·0	24-44	
Indigenous canes...	1911-13	1	19	48·0	......	*Cheni* alone 48
	1912-14	3	145	42·8	41-44	*Cheni* 44, *Saretha* (with shoots 52) 45
	1914-16	3	108	36·6	34-40	*Cheni* 35, *Saretha* 40, *Pansahi* 34
	1915-17	1	100	21·0	......	*Khelia* alone 21
	1916-18	4	304	18·5	17-21	*Pansahi* 18, *Khelia* 21
Crosses, thick canes by thick	1913-15	3	158	14·6	14-15	
	1916-18	1	132	7·0	......	*Vellai* × *J. 247*, a good tillering variety
Crosses, thick canes by thin	1913-15	3	54	22·0	18-24	
	1915-17	2	127	20·4	20-21	These are general collections from *Kaludai Boothan* and *Chittan*. The register says "probably crosses with *Naanal* seedlings," hence probably a mixture of crosses and selfs
	1916-18	9	956	12·8	10-15	
Crosses, thick × thin (*J. 213*), by thin	1916-18	3	441	17 9	17-19	*J. 213* selfed and unbagged crosses with thin canes: probably a mixture of selfed seedlings and crosses
Crosses, thick by *Saccharum Narenga*	1913-15	1	94	29 0	......	*Vellai* × *Saccharum Narenga*, a not very bushy form
Crosses, thin by *Saccharum spontaneum*	1912-14	1	62	81·0	......	*Saretha* × *Saccharum spontaneum*, both parents very bushy

Where comparisons are obtainable, the rainfall of 1913–15 appears to have made itself felt, and possibly the high rate of tillering of the *Karun* seedlings may have been partly influenced by it. The converse may be the case in 1916–18, a year of badly distributed and meagre rainfall. But the crop is plentifully irrigated and the influence of rainfall on the tillering is perhaps more apparent than real. The quantity of prepared earth and the spacing are much more likely to affect the tillering of the canes. This is quite obvious in the jumps from 1915–17 to 1916–18, but less so before that time. In the thick cane seedlings, indeed, there is little difference (15-13), but, where thin canes enter as parents, in part or whole, the decline in tillering is more marked, as it is also in the very aberrant rogues, formed among the thick cane seedlings. Rogues, 69, 97, 88, 56, 47, 30 : thin canes, 48, 43, 37, 21, 18 : *Cheni* 1911–13 (48), 1912–14 (44), 1914–16 (35), and so on. We are justified in concluding that the thick canes have been little inconvenienced by the narrowing of their limits in the field, owing possibly to the sparse nature of their branching ; the thin canes, however, with their greater tillering power, have become considerably hampered in their development in the successive restrictions, in spite of the general improvement of the land since the farm was opened.

We can also see from the table that a study of the numbers of canes produced at crop time places in our hands a useful means of detecting whether an attempted cross between a thick and thin cane has succeeded, and we have become accustomed to use this character whenever in doubt on the subject (*cf.* Remarks on thick and thin canes in 1915–17 in the table). There is, generally, a constant increase in the numbers of canes as we proceed from pure blooded thick canes, through crosses between thick and thin, to such as have more thin than thick parentage and, finally, to such as have *Saccharum spontaneum* added.

(2) In cultivated canes.

With regard to the ordinary cane varieties planted from sets, it is well known that they differ a good deal in their amount of tillering. Thus the indigenous Indian canes tiller much more freely than the thicker canes of the tropics. This is the common experience of the Cane-breeding Station and, what is more, the descendants of these two classes of cane varieties inherit their parents' characters in this respect. Details regarding the Indian canes are few and far between. Practically the only comparative statement we have come across is one regarding canes grown at Sabour in Bihar.[1] In

[1] Woodhouse, Basu and Taylor. The distinguishing characters of sugarcanes cultivated at Sabour. *Mem. Dep. Agri., Ind., Bot. Ser.,* Vol. VII, No. 2, April, 1915.

this statement it is seen that the average number of canes per clump, in the thin Indian varieties grown there, is 8–16, in the half-thick forms (*Khelia*, *Striped Bansa*, *Puri* and *Sukli*) 7–8 (*Dahlsunder* 5·5), and in the thick, imported varieties, 4–6. It is not possible to deduce accurate acreage numbers from the table, because the details are not given of the space occupied by the clumps investigated. But the plants were put in at about 6,000 to the acre, and, assuming that the countings would not be taken where clumps had failed, as this would vitiate the results because of different spacing, we get, for the thin canes, 48,000–96,000 canes per acre, for the half-thick, 42,000–48,000, and, for the thick, 24,000—36,000. The latter figure tallies fairly well with those obtained for the cane varieties grown in the tropics. Numerous data can be obtained for these, and I have selected a few at haphazard from various sources.

Louisiana : *Purple* cane, 35,000.

Java : *Cheribon*, 20,000 ; *J. 247*, 31,500 ; *J. 36*, 32,000 ; *J. 100*, 28,600.

Madras (Godavari delta) : *Namalu*, 25,000 ; *Mogali*, 20,000 ; *Keli*, 31,000 ; *Seema*, 22,000 ; *Yerra*, 37,500, etc.

In almost all of these cases we note that, the thicker the cane, the fewer there are to the acre, and the general observation of this fact has led various writers to suggest that, given similar conditions of soil, climate and treatment, practically the same weight of cane may be reaped per acre whatever the variety may be. This principle appears to be fairly well established, provided that the cane varieties compared belong to the same natural class. A rather striking confirmation of this principle, that thickness and canes per acre are negatively correlated, may be seen in the following table, the details of which have been extracted from Memoir III, where the Saretha and Sunnabile groups of canes are contrasted (*cf.* pp. 166–167 and 169). These canes were all grown on adjacent plots under the same conditions.

Saretha Group			Sunnabile Group		
Variety	Canes per clump	Thickness in cm.	Variety	Canes per clump	Thickness in cm.
Chin ...	29	1·5	*Kaghze* ...	20	1·6
Saretha (green) ...	28	1·7	*Bansa* ...	18	1·8
Khari ...	24	1·8	*Sannabile* ...	17	1·9
Hullu Kabbu ..	22	1·9	*Naanal* ...	15	2·1
Ganda Cheni (poor)...	16	2·0	*Dhor* (poorly grown)	12	2·2
Average ...	24	1·8	Average ..	16	1·9

In this table the varieties of each group (all that were measured) are arranged in order of tillering power and, in the second column, where the

Tillering of Indian canes in different localities and under different treatment, 1917-18 *crop.*

Name of Station	Treatment	Soil	Rainfall	No. of irrigations	Spacing	Variety	Group	No. of clumps	Average canes per clump	Average* canes per acre	REMARKS
Aligarh	Sugarcane planted in alternate years: 6 ploughings and 500 maunds of farmyard manure	Deep alluvium, soft and powdery under cultivation	25″	15	Rows 1′ apart; sets 6″ in row. Per acre 20,000–30,000	Saretha	Saretha	500	1·96	49,000	Saretha badly smutted.
						Chin	do.	500	3·50	87,500	Canes lodged and stools not distinguishable. Numbers therefore calculated from planting record.
						Khari	do.	500	2·40	60,000	
						Sunnabile	Sunnabile	500	2·00	50,000	
						Yuba	Pansahi	500	2·06	51,500	
						Mungo	Mungo	500	4·00	100,000	
Shahjahanpur ..	Sugarcane planted once in 3 years: 20 ploughings and 15 maunds of castor cake	As the last, but finer	65″	1	Rows 2½′ apart; sets 4-6″ in row. Per acre 15,000	Saretha	Saretha	100	7·50	112,500	
						Chin	do.	100	9·00	135,000	
						Khari	do.	100	5·85	87,750	
						Maneria	Pansahi	100	5·83	87,450	
						Manga	Nargori	100	5·88	88,200	
						Mungo	Mungo	100	9·97	149,550	
Partabgarh ...	Sugarcane planted once in 3 years: 7 ploughings and 300 maunds of cattle manure with 50 maunds of castor cake	Deep loam, coarser than the last	46″	5	Rows 1½′ apart; sets about 1′ in row. Per acre 16,000	Saretha	Saretha	100	5·95	95,200	(1) had lighter soil than (2); had 500 maunds of cattle manure against 300 and fewer irrigations.
						Chin	do.	100	8·88	142,080	
						Pansahi (1)	Pansahi	100	7·11	113,760	
						do. (2)	do.	100	5·44	87,040	
						Nargori	Nargori	100	7·33	117,280	
						Rheora	Mungo	100	6·77	108,320	
Benares	Sugarcane planted once in 3 years: 8 ploughings and 200-300 maunds of cattle manure	Shallow reddish loam	54″	8	Rows 1½′ apart; sets about 8″ in row. Per acre 15,000	Saretha	Saretha	100	7·65	137,700	
Pusa	Sugarcane planted once in 3 years: 6 ploughings and 6 tons of farmyard manure and 6 maunds mustard cake	Deep alluvium, fine and powdery under cultivation	43″	0	Rows 2½′ apart; 1-2″ between sets. Per acre 16,000	Saretha	Saretha	100	8·13	130,080	
						Naanal	Sunnabile	100	7·44	119,040	
						Chynia	Pansahi	100	6·22	99,520	
						Maneria	do.	100	9·66	154,560	
						Yuba	do.	100	9·48	151,680	
						Mungo	Mungo	100	8·22	131,520	
Sabour	Sugarcane planted once in 3-4 years: trenched 6″ deep: 200 maunds of cattle manure and 10 maunds of rape-seed cake	Shallow clayey loam	40″	10 to 15	Alternate rows 2′ and 4′ apart; sets 2-3′ in row. Per acre 8,000	Saretha	Saretha	50	10·00	80,000	
						Khari	do.	50	9·25	74,000	
						Pansahi	Pansahi	30	9·80	78,400	
						Chynia†	do.	50	9·35	74,800	
						Nargori	Nargori	40	9·75	78,000	
						Baroukha	do.	50	9·00	72,000	
						Mungo†	Mungo	50	11·23	89,840	
						Rheora	do.	50	12·90	103,200	
Sindewahi	No regular rotation: 6 ploughings and 5,000-7,000 sheep folded, with 30 maunds of castor cake	Shallow sandy loam	30″	30	Rows 2-2½′ apart; sets 1-1½′ apart, across the rows. Per acre 12,000–16,000	Saretha	Saretha	100	9·00	126,000	
						Chin	do.	100	10·21	142,440	
						Khari	do.	50	8·67	121,380	
						Sunnabile	Sunnabile	100	8·72	122,080	
Samalkota	Sugarcane planted once in 4 years: crowbarred after paddy: 1,640 lb. of castor cake	Heavy black alluvial clay	48″	8 to 10	Rows 2½′ apart; sets 3-6″ in row. Per acre 12,000–15,000	Saretha	Saretha	36	6·40	86,400	
						Chin	do.	41	8·00	108,000	
						Khari	do.	39	5·30	71,550	
						Pansahi	Pansahi	41	5·50	74,250	
						Chynia	do.	34	5·70	76,950	
						Baroukha	Nargori	31	6·70	90,450	
						Mungo	Mungo	40	7·66	103,410	
Cane-breeding Station at Coimbatore	Canes planted once in 3 years: 8 ploughings: trenches dug 1′ deep and 1′ broad: green-manuring, contents of weed pits and 1,000 lb. of ground-nut cake and about 10 tons of cattle manure	Light but slightly saltish sandy loam	22″	40 to 50	Rows 3′ apart; sets 2′ apart, across the rows. Per acre 7,200	Saretha	Saretha	7	13·00	93,600	These numbers are extracted from the succeeding list for the purpose of comparison.
						Chin	do.	14	12·70	91,440	
						Khari	do.	7	11·00	79,200	
						Sunnabile	Sunnabile	14	12·55	90,360	
						Naanal	do.	7	9·70	69,840	
						Pansahi	Pansahi	14	12·30	88,560	
						Maneria	do.	14	10·20	73,440	
						Yuba	do.	7	12·10	87,120	
						Chynia	do.	7	8·00	57,600	
						Nargori	Nargori	16	16·00	115,200	
						Baroukha	do.	24	15·67	112,824	
						Manga	do.	8	18·80	135,360	
						Mungo	Mungo	14	16·00	115,200	
						Rheora		7	15·40	110,850	

* These figures of canes per acre are purely theoretical, being obtained from the spacing and tillering figures, on the assumption that every set sprouted and that the whole field was uniform. They are thus only of use for general comparison.

† These countings were taken from the farm area where the treatment was practically the same as in the varietal plots.

relative thickness of the canes is given, the order is seen to be exactly reversed. Too much weight must not of course be attached to this interesting result, for the relative differences are by no means proportional, and a comparison of the averages of the two groups is instructive as showing that the class of cane has influence; but a similar result, with many exceptions, is to be found in the longer tables appended, of thickness and tillering power of the varieties of the different groups in the 1917-18 crop on the Cane-breeding Station. Tillering and thickness of cane are inherent characters in each variety and group, but we must limit their correlation to the members of the same group. Thus, the Mungo class are among the thickest of the indigenous canes, being short and bush-like, and their tillering power is very great; on the other hand, the Nargori group contain, on the average, the thinnest Indian canes, and their tillering power is practically the same in the table as that in the Mungo class. Mere thickness cannot therefore be taken as a character from which tillering power can be deduced, but the group character must also be taken into account. In these and other comparisons, the thick canes, tropical, are generally taken as one class, because there is at present no classification prepared for them, as for the Indian canes. It is certain that great differences exist, which should be worked out in order to introduce a proper classification in them also. (See, however, Jeswiet's recent papers on this subject, where a series of descriptions of thick canes has been commenced. The inaugural paper has been referred to on page 56 above.)

Two tables are appended containing observations on the tillering of different Indian cane varieties during the 1917-18 crop season. The first of these contains observations and measurements made at my request by Mr. T. S. Venkataraman, during a tour in December and January last, when he visited a number of North Indian agricultural stations, where certain varieties were being grown, of which a series of measurements were desired for another piece of work. The chance of obtaining some idea of their tillering capacity was too good to be lost, but the observations were confined to the varieties being studied. These varieties were those also being grown on the Taliparamba and Samalkota farms in Madras, namely *Saretha*, *Chin* and *Khari* of the Saretha, *Pansahi* and *Chynia* of the Pansahi, *Baraukha* of the Nargori groups, and *Mungo* as representative of its own group. To these were added, where possible, one of the Sunnabile group, and, on account of the great similarity among themselves of the members of the Pansahi and Nargori groups, a certain amount of substitution was allowed in them where necessary. The observations were thus limited to certain varieties representing the different groups of indigenous canes, and are chiefly interesting as showing how greatly the same

canes vary in tillering capacity in different localities and under different conditions. First in importance of these conditions is the rate of sets planted per acre, but the general treatment, kind of soil, rainfall and irrigation also have influence, and notes on these are appended in the table. Making every allowance for these differing circumstances, we still see that the same cane differs much in its tillering power in different parts of the country, and, to make this more evident, a column has been inserted giving the numbers of canes per acre, in each case calculated from the number of sets sown per acre, and the average number of canes per clump. The figures in this column are not to be taken as an accurate estimate of canes per acre, in that they assume that every set grew into a plant, and that the part of the plot where the canes were counted was characteristic of the whole. The figures are of more use in comparing the relative branching of the canes in the different farms, than of the crops obtained. Taking this character of tillering as inherent in the variety, this variation is not surprising, for we have found similar differences to occur in almost every other character of the cane. The comparison of such other characters has been prosecuted for several years, and it is hoped will form the subject of another Memoir shortly. The length and thickness of the cane, the number of joints, the relative length of cane and shoot, the width and length of the leaf, the rate of maturing of the cane and the number of dead leaves adhering to the stem at different periods of growth, all of these characters have been found to vary profoundly, in the same cane, in different localities in India, and we have noted that the locality impresses itself on the plant produced to such an extent, that a survey of the series of measurements will generally enable us to determine in what part of the country the cane has been grown. A large number of deductions could be drawn from this table of tillering, but it is felt that these are foreign to our present purpose and, also, that the figures, having been obtained for one year only, require confirmation and extension, and it is hoped that this will be done by those in charge of the various farms. It may be noted in passing, however, that one of the most interesting results obtained is the way in which certain varieties seem to be adapted to certain localities, an aspect of the question which will be dealt with in the Memoir proposed.

The second table contains observations, also made at my request by Mr. T. S. Venkataraman, at crop time on the Cane-breeding Station, in April 1918. The cane plots on the farm are small, each consisting of one variety in three rows about 20 feet long. A space separates each plot from the rest in the form of a dropped row. For the tillering figures one row was selected in each plot, where possible the central one, but, where this had been used for other purposes,

an end row was taken and this is noted in the table. It was presumed that, because of greater space, there might be more canes in an end than in the central row, but this does not seem to be so to any great extent, and the position of the row may accordingly be neglected, as of little influence on the general results.

The number of clumps examined in these observations is therefore extremely limited, especially as the end clumps of each row, that is, those next to the irrigation channel and the drain at the other end, were excluded. The table is less to be relied on than the preceding one, but the general results agree well enough with those obtained on the farm in other years. The average thickness of the canes in the plot has been added, and this was computed from the average of 100 canes in each case. In this table, the varieties in each group are arranged in the order of greatest tillering. Comparing the average rates of tillering, we see that Mungo and Nargori groups head the list with 15·1 canes per clump; these are closely followed by the brown section of Saretha, then, in succession, the series of unclassed canes, Sunnabile group, Pansahi group and, last of all, the green section of the Saretha group, with 9·5 canes per clump. As regards thickness, Mungo heads the list and Nargori shows the thinnest canes. But both of these have the greatest tillering power, a fact that has already been commented on. The following summary table shows that, with the exception of Mungo and the green section of Saretha, the average thickness of the canes in a group varies more or less inversely with the rate of tillering.

Name of group	No. of varieties	Average thickness in cm.	Average No. of canes per clump
Mungo	32	2·60	15·10
Nargori	13	1·60	15·10
Saretha (brown)	13	1·62	14·00
Unclassified list	21	1·87	13·60
Sunnabile	22	1·90	12·55
Pansahi	17	1·95	11·00
Saretha (green)	10	1·86	9·50

Canes per clump and average thickness of canes in the varieties grown on the Cane-breeding Station, 1917-18.

	No. of clumps	Plot No.	Position of row	Av. thickness of cane in cm.	Av. No. of canes per clump
Mungo group					
Matna (Shahj.)	7	2641	end	1·70	24·6
Matna Ukh (Cawnpore)	7	2642	do.	1·95	22·7
Matki Mungo	7	2658	central	1·70	21·7
Kharwi	7	2656	do.	1·55	20·1
Reori	7	2644	do.	1·65	19·7
Matna (Aligarh)	7	2640	do.	1·85	19·0
Katara (Partabg.)	7	2648	end	2·10	18·7
Sarauti	7	2650	central	1·65	17·9
Lewari	7	2638	do.	2·05	17·9
Mungo (Sabour)	7	2626	end	2·25	17·6
Kuswar (Ottur)	7	2635	do.	2·25	17·1
Kuswar (Aligarh)	7	2636	central	2·35	15·6
Rheora	7	2643	do.	1·90	15·4
Patarki Mungo	7	2657	do.	2·10	15·1
Kuswar (Partabg.)	7	2637	do.	1·95	14·9
Mungo (Aligarh, Partabg.)	7	2627	do.	1·95	14·4
Khatuia	7	2645	end	2·20	14·1
Hemja (Bhikanpur)	7	2629	do.	2·30	13·9
Dark Pindaria	7	2655	central	1·50	13·7
Katara (Barah)	7	2647	end	2·20	13·6
Matanwar	7	2653	central	2·30	12·6
Paunri	7	2628	end	2·20	12·4
Agoule	7	2646	central	2·20	12·4
Burli	7	2633	end	2·15	12·1
Pararia	7	2652	central	2·15	12·0
Hemja (Sab. 2 E.)	7	2630	end	2·20	11·3
Foraya	7	2639	central	2·40	11·1
Hemja (Sab. 2 B.)	7	2631	end	2·30	11·0
Pararia	7	2651	central	2·15	10·7
White Pararia	7	2654	end	1·90	10·6
Buxaria	7	2632	central	2·20	9·4
Ramgol	7	2649	do.	2·30	9·0
32 Varieties	...	...	...	65·90	482·3
Average	...	...	...	2·06	15·1
Saretha (Brown)					
Raksi	7	2659	central	1·35	20·0
Ramui	7	2661	end	1·60	19·1
Lalri	7	2662	do.	1·55	16·1
Baroukha Ukh	7	2666	do.	1·70	15·9
Chunnee	7	2665	central	1·60	15·3
Burra Chunnee	7	2669	do.	1·70	14·3
Chin (Aligarh)	7	2663	do.	1·40	14·0
Saretha	7	2670	do.	1·85	13·0
Kansar	7	2667	end	1·75	12·9
Chynia	7	2668	do.	1·75	11·6
Katha	7	2660	central	1·45	11·6
Chin (Partabg.)	7	2664	do.	1·50	11·1
Saretha Desi	7	2671	do.	1·55	7·1
13 Varieties	...	...	...	21·05	182·0
Average	...	...	...	1·62	14·0

Canes per clump and average thickness of canes in the varieties grown on the Cane-breeding Station, 1917-18.

	No. of clumps	Plot No.	Position of row	Av. thickness of cane in cm.	Av. No. of canes per clump
Saretha (Green)					
Dhaur Saretha	7	2674	end	1·80	11·7
Khari (Jubbulpore)	7	2677	central	1·90	11·0
Mesangan	7	2672	do.	1·50	10·9
Hullu	7	2678	do.	2·00	10·6
Kalkya (Satara)	7	2650	do.	1·85	9·4
Jaganathia	7	2675	do.	1·90	9·0
Ganda Cheni	7	2679	do.	2·00	8·6
Kalkya (Dharwar)	7	2681	do.	2·10	8·3
Saretha	7	2673	do.	1·65	7·7
Khari (Sabour)	7	2676	do.	1·90	7·7
10 Varieties	...	...	...	18·60	94·9
Average	...	..	...	1·86	9·5
Sunnabile group					
Teru (Harchowal)	7	2683	central	1·40	26·0
Ketari (12 A Sab.)	7	2690	do.	1·60	21·4
Bansa (E 51 do.)	7	2692	end	1·55	18·3
Rakhra (Partabg.)	7	2684	central	1·60	16·1
Ekar	7	2686	do.	1·65	15·4
Dhaulu	7	2687	do.	1·55	14·7
Teru (Gurdaspur)	7	2682	do.	1·45	14·0
Ketari (20 E Sabour)	7	2691	do.	1·65	14·0
Rakhra (Shahj.)	7	2655	do.	1·70	13·9
Sunnabile (Jub.)	7	2696	do.	1·95	13·7
Bansi	7	2694	end	2·10	12·7
Kaghze (Pilibhit)	7	2689	central	1·70	12·6
Kaghze (Aligarh)	7	2688	do.	1·65	12·1
Sunnabile (Jub.)	7	2695	do.	2·10	11·4
Naanal	7	2700	do.	2·10	9·7
Khadya (Nasik)	7	2698	do.	2·15	9·1
Putli Khajee	7	2697	do.	2·25	9·1
Mojorah	7	2704	end	2·50	8·0
Khadya (Dharwar)...	7	2699	central	2·50	7·4
Hotte Cheni	7	2701	do.	2·40	6·7
Dhor	7	2702	end	2·35	5·6
21 Varieties	...	...	...	39·90	271·9
Average	...	...	...	1·90	12·95
Pansahi group					
Pansahi (E 57 Sab.)...	7	2717	central	2·00	12·6
Sada Khajee	7	2719	end	1·85	12·3
Kahu (Irrigated)	7	2712	central	1·95	12·3
Kahu (Rain-fed)	7	2713	end	1·85	12·1
Thin Moulmein	7	2072	central	2·00	12·1
Yuba (Natal)	7	2710	do.	1·95	12·1
Pansahi (E 58 Sab.)...	7	2718	end	2·00	12·0
Sanachi	7	2709	central	1·95	11·9
Ketari (20 A Sabour)	7	2705	end	2·0)	11·7
Merthi	7	2707	central	2·00	11·6
Maneria (E 56 Sab.)	7	2716	do.	2·00	11·3
Lata	7	2714	do.	1·80	10·1
Dikchan	7	2708	do.	1·90	9·7
Bharanga	7	2720	do.	2·05	9·4
Ketari (20 H Sab.)	7	2706	do.	2·10	9·3
Maneria (E 55 Sab.)	7	2715	do.	2·00	9·1
Chynia (E 39 Sab.)	7	2711	do.	1·80	8·0
17 Varieties	...	...	...	33·20	187·6
Average	...	...	...	1·95	11·0

Canes per clump and average thickness of canes in the varieties grown on the Cane-breeding Station, 1917-18.

	No. of clumps	Plot No.	Position of row	Av. thickness of cane in cm.	Av. No. of canes per clump
Nargori group					
Agoule No. 2	8	2733	central	1·55	19·6
Baroukha (Pursa)	8	2725	end	1·55	19·1
Manga	8	2732	central	1·60	18·8
Nargori (15 D Sab.)...	8	2722	end	1·60	17·9
Kewali (15 G Sab.)	8	2724	do.	1·50	16·5
Mungo (Sic.)	8	2736	do.	1·65	15·9
Baroukha (Shahj.)	8	2727	do.	1·65	14·8
Reora	8	2737	central	1·50	14·8
Kewali (14 B Sab.)	8	2723	end	1·70	14·3
Nargori (15 B Sab.)...	8	2721	central	1·50	14·1
Kalari	8	2734	do.	1·55	14·1
Ketari (12 D Sab.)	8	2728	do.	1·65	13·5
Ketari (12 J Sab.)	8	2729	do.	1·60	13·5
Baroukha (13 A Sab.)	8	2726	end	1·65	13·1
Chynia (E 41 & 42 Sab.)	8	2730	do.	1·70	12·3
Sararoo	8	2731	central	1·60	12·3
Katai	8	2735	do.	1·65	12·1
17 Varieties	...	...	...	27·20	256·7
Average	...	...	...	1·60	15·1
Unclassified					
Dhaur (Aligarh)	8	2741	central	1·80	20·9
Shakarchynia	8	2758	end	1·80	19·4
Dhaulu (of Phillaur)	8	2739	do.	1·65	18·9
Bodi	8	2738	do.	1·75	18·6
Kinar	8	2745	central	1·65	16·1
Khagri (19 D Sab.)	8	2749	end	1·90	15·6
Kanara	8	2747	do.	1·75	15·3
Barhai (Jub., Gurdaspur)	8	2755	central	1·40	15·1
Barhai (Jub.)	8	2756	end	1·40	15·1
Kinar	8	2744	central	1·75	14·9
Betakali	8	2740	do.	2·30	13·4
Dhaur Kinar	8	2746	do.	1·70	12·8
Dhaura (Azimgarh, Gurdaspur) ..	8	2743	do.	2·00	12·6
Agol	8	2748	do.	1·85	12·1
Khagri (Dacca)	8	2750	end	1·90	11·3
Baroukha (Shahj.)	8	2757	do.	2·00	10·8
Dhaur (Shahj.)	8	2742	central	1·95	10·4
Ikri	8	2752	do.	2·30	9·7
Khagri (Rajshahi)	8	2751	do.	2·10	9·6
Khelia (E 54 Sab.)	8	2754	do.	2·20	8·0
Khelia (E 53 Sab.)	8	2753	do.	2·15	7·3
21 Varieties	...	...	...	39·30	287·9
Average	...	...	...	1·87	13·6

On studying the relation between thickness and rate of tillering in the varieties of each group, we must remember that the fewness of the clumps examined has much greater influence in the variety than in the whole group. We also note that in the Nargori and Pansahi varieties the thickness varies within very narrow limits, and it is not surprising that no correlation can be established. The green section of the Saretha group also shows no correlation,

but, in the rest, there is a marked tendency for the thinner forms to have greater branching. For safe deductions on this point, a much larger number of clumps must be available for examination.

(3) Deaths during growth and the period of maximum tillering.

In considering these and other tables on the tillering power of different varieties of canes, founded on the number of canes produced at harvest, it is necessary again to sound a note of warning at the somewhat loose use of the term in general practice. The total number of canes at crop time is not in reality a safe guide to the shooting power, or tillering capacity in its narrower sense, because a large number of shoots die during the life of the plant. This is a necessary result of cultivation, where a tufted grass is forced to grow within narrow limits, so as to obtain as many matured stalks as possible. There is not room for the development of a number of the shoots formed and hence the mortality among them is very considerable. Stubbs,[1] in his careful experiments on the *Purple* and *Striped Louisiana* canes in 1894-95, calculated that the deaths of shoots during growth were 58·9 per cent. in 1894 and 53·9 per cent. in 1895. Muller von Czernicki, in Java, counted the number of shoots appearing above ground at varying periods between 60 and 150 days, and showed conclusively that the numbers were far greater at the earlier than the later period. Thus, in *Cheribon* 120–180 shoots were counted in different plots at 60 days from planting and only 60–70 at 150 days ; the figures for *J. 247* were 160–240 and 90–100, and, for *J. 100*, 100–170 and 82–86 respectively. Strüben, in a series of experiments on *J. 247*, found that the better grown plots in the first two or three months gave 300–400 shoots per row, in one case the number reaching 415, whereas at eight months all of the rows gave only about 110 shoots. No data are as yet available as to whether Indian canes suffer this great mortality during the earlier period of growth, but there is some reason to suspect, from shoot-counting observations, that it is a much less serious factor than in the thick canes, and further countings have been commenced to settle the question.

Another point to be held in view is the relative rate of germination and tillering in different varieties. This of course does not refer to the effect of cold and drought, as for instance in North India where the early growth is so much slower than in the Indian Peninsula, but only includes comparisons where the conditions are altogether as similar as it is possible to make them.

[1] References to these papers will be given later.

We find that there is a considerable variation in different canes in this respect, as can be readily demonstrated in comparing the Saretha and Sunnabile varieties on the Cane-breeding Station (*cf.* Mem. III, p. 149). Muller von Czernicki found in his shoot-counting experiments, that *Cheribon* reached its maximum number of shoots at 60 days from planting, *J. 100* at 90 days, while *J. 247*, although having more canes at harvest than either of the others, was slower and later in its early stages (*cf.* Pls. XIV and XV). In comparing the maximum number of shoots formed in any variety, it is not safe, then, to count the number of shoots in the plots at any one time, but the rate of development must be held in view, so as to get a true maximum for each variety, and from this to deduce the number of deaths occurring. For a time the numbers of shoots formed exceed the deaths and the total numbers steadily rise in the plots, but a period soon supervenes when there are many more deaths than new formations and, once this period has been reached, there is a continuous and great reduction in total numbers; later on, a sort of equilibrium is reached, when the activity of fresh formation wanes and the shoots are of sufficient vigour and size to be able to maintain themselves and grow to maturity.

4) Artificial interference with tillering.

The great mortality of shoots during growth is obviously of serious import from the crop point of view. Not only is the possible number of canes diminished, but the formation of such numbers of abortive shoots must be a serious drain on the reserves of the plant. Attempts have accordingly been made from time to time to limit the tillering of the sugarcane by artificial means. It is the common practice with many crops to thin the plants out when they have become established, thus assuring a full stand with plenty of room for the development of each plant. This practice is hardly applicable to the present case, which is more analogous to the thinning out of branches in pruning and removing an excessive number of fruits or flowers for the better development of those that remain. Rosenfeld conducted some experiments at Tucuman on the effect of the thinning out of cane shoots on the crop, but found that the results from this procedure were rather adverse than otherwise.[1] These experiments, are however, open to serious criticism and cannot be regarded as demonstrating the inadvisability of the practice of thinning. His experiments were conducted on a single plot of canes, half of which was thinned

[1] Rosenfeld, A. H. Experiments in thinning out sugarcane rows. *International Sugar Journal*, 1914, p. 220, and 1918, p. 20.

and the other left intact. There was no control or duplicate plot. He repeated the thinning operation each year on the same plot, where the canes were grown, to first, second, third and fourth ratoons. It would be a mistake to assume that these successive experiments on the same plot were in any way a substitute for proper control plots, in that any fault in the original selection would but be repeated each year. Besides this, it is quite possible that ratoons may behave differently to plant canes in this matter, and also among themselves, whether first ratoons or those of a higher order. No hints are given as to the character of the season in each year, although there are intrinsic evidences that these differed, and it is quite reasonable to suppose that the thinning would have a different value according to the season, and consequent general health and growth of the plants. Lastly, no preliminary experiments appear to have been made at the correct time of thinning. The plot was planted in June, it was thinned in March "*where it was thought necessary,*" "*by removing suckers and small canes where there was an abundance of larger better grown stalks,*" and the crop was reaped in July. It would seem natural that this late removal of small canes would act prejudicially on the weight of the crop at harvest, and the canes were also naturally, on the average, thicker as well as fewer in the thinned plots. For a decisive result on the effect of thus artificially restraining tillering, the thinning should be carried out systematically throughout the plots, separate plots should be thinned at different periods of growth, and a reasonable number of controls should be introduced.

In Louisiana, profuse tillering is a matter of some moment because of the shortness of the season. For the best results to be obtained, it should be great in the earlier part and small or absent at the end of the season. This has been very clearly explained by Stubbs,[1] and a further danger in late tillering has been pointed out by him. Shoots developed after July 1 are not likely in Louisiana usually to mature before the cold weather sets in. Furthermore, late tillering and shooting of the aerial buds destroys the evenness of the stand in the ratoons of the following year, as these are (presumably) killed during the cold weather. Stubbs therefore paid very marked attention to the matter for several years, and adopted various methods which, he thought, might regulate the branching of the cane at different periods of growth, his desire being to stimulate the early and restrain late formation of branches. His general conclusions are summed up in the statement that tillering is a natural property of the cane and cannot be prevented. As the result of his experiments

[1] Stubbs, W. C. *Sugarcane*, Vol. I, Chapter XIV, Suckering of cane.

he, however, suggests that continued working between the rows without injuring the roots might act as a restraining influence on too late branching.

The earthing up of the cane rows is a well-known practice, both for the purpose of drainage and the provision of suitably prepared nutriment, and for giving the plants a firm hold on the ground when they are tall and stormy weather prevails. It is customary in Java for this operation to be performed at stated intervals, and there appear to be four successive earthings up, during the first four or five months of the plants' growth. This practice, as with all the agricultural operations on the cane field, is doubtless the result of numerous careful experiments during past years. From what we have stated regarding the different phases of growth in grasses, we should naturally assume that the heaping of earth over the base of the cane plant would, by lengthening the period of underground branching, tend to increase the tillering. But it seems to be held by many in Java that earthing up tends rather to restrain tillering. As, however, the opinions expressed from time to time have been very conflicting, Strüben[1] and others have conducted experiments to see if tillering was affected by delaying the earthing up. Strüben's general conclusion is that the time of earthing up has little or no effect on the general crop result. In another paper he deals with other matters, such as manuring and spacing, and comes to the same general negative result, and it is worth while drawing attention to the fact that he would almost seem to hold a brief for the non-effect of these various operations, whereas it occurs to us as quite possible that another worker might have come to a somewhat different conclusion on the facts quoted by him. We shall refer to this in more detail later on.

(5) On the factors influencing tillering.

Of all the factors influencing tillering, perhaps the most important is light, but the provision of other needs of the growing plant, such as warmth, moisture, soil constituents and manuring must also be considered. Lastly, the space available is of immediate effect, because of the interference of the shoots with one another and the varying amount of light and food in all its forms which may be obtainable. It should be obvious that tillering, being an essential characteristic of the growth of the plant, will be assisted by anything that induces a better physical condition.

The influence of *Light*. We have seen that deeply planted grass seedlings at once set about an attempt at reaching the proper place for tillering, near the

[1] Strüben, W. Vroege of late aanaarding? *Archief v. d. Suikerind. in Ned. Ind.*, Bijblad, 1909, p. 592.

surface of the soil. A similar contrivance has been shown to exist in certain young sugarcane seedlings (p. 47), but observations have not been recorded as to this habit in deeply planted sugarcane sets. In our dissections, however, we not infrequently meet with what might be termed upright runners, in which, long, thin internodes are intercalated between the usual, congested short internodes of the base, and doubtless the meaning of this is sometimes the same as that in seedlings, in that thereby the underground part may be placed in the best position for rapid branching, near the soil surface. Tillering cannot take place satisfactorily unless the shoots are able immediately to emerge into the light. But when a certain number of branches have been developed, and the light space so to speak is filled, further shoots are at a disadvantage in that they are overshadowed by their neighbours. This is undoubtedly the cause of the great mortality in cane shoots during the growth of the crop, and it is not easy to see how this perfectly natural effort at producing as many branches as possible can be prevented, if the plant itself has not the power to adapt itself to the conditions. It is fairly certain that this death of shoots is not due to the lack of food supply in the soil, for this can be and, habitually, is supplied to meet all possible needs. Generally speaking, all plants in the light branch more freely than in the shade. Growth in length is repressed in light and a more spreading habit is induced which gives room for more shoots to be developed. As one author has justly argued, of all the food producers on which the plant is dependent, light is the only one over which we have no control. There is a definite amount of light available for each area, and this we cannot increase by any means, whereas air is moving, and water and salts can be applied artificially. We can increase the depth of soil and the amount of water, can improve the physical condition of the soil and add manures as desired, but, as soon as the amount of light available is fully occupied, the further branches are shadowed and unhealthy, however many we may by various means cause to be developed. It is a common experience that trees on the outside of a forest, or in free space, are much larger and more uniformly developed than those within the forest, and this is not only due to their greater command of the soil around but also to the light available, and the same applies to cane plants near the edges of the fields or along the sides of the paths. The problem of obtaining the greatest number of canes per acre is thus seen to be strictly limited by this factor, as well as by those of cultivation and manuring. Light is perhaps the most important limiting factor as regards tillering.

Moisture also undoubtedly affects tillering, as can be seen by studying the plants along the irrigation channels where they are as closely planted as

elsewhere. The frequent advantage of plants so situated should be carefully noted, as suggesting that full use is not always being made of watering facilities. There is still a good deal of work to be done with regard to the effect of the duty of water on the number of canes to be obtained under varying conditions of soil and manuring.

Manuring naturally has its effect on the number of canes produced as well as their individual weight and the richness of their juice. A careful study of this effect has been made by Kilian, who desired to know the best manures to be applied to the three cane varieties which appeared to be suited to the different soils in his estate at Poerwodadi in Java.[1] Although his research was limited to a purely utilitarian problem, the care with which his experiments were conducted renders them valuable from the scientific point of view, and their limited range is of no disadvantage in this respect. The experiments were with *Black Cheribon* and *J. 247*, which were canes growing well in his conditions, and consisted of a series of plots to which were added varying amounts of sulphate of ammonia, superphosphate and cattle manure. Besides studying general yield and other matters, he counted the number of canes at harvest, and this renders his paper of interest to us. Briefly the results were as follows :—

In *Black Cheribon*, with the same amount of sulphate of ammonia, increasing doses of superphosphate gave a gradual rise in the weight of cane and of sugar per acre ; also there was an increase in the number of canes, but this was less regularly the case. With increasing doses of sulphate of ammonia, the numbers of the canes varied irregularly, whereas the weight of canes and of sugar gradually increased. With the addition of a suitable amount of cattle manure to a moderate amount of both of these artificial manures, there was a distinct rise in the numbers of canes in the plots, as well as weight of cane and of sugar at crop time. The experiments with *J. 247* seem to have been confined to the ammonium sulphate series, and the results were similar to those with *Black Cheribon.*

These experiments were carried out on soils varying from heavy black clay to thin dry loam, and we see that the addition of quantities of suitable manure, especially cattle manure, lead to a distinct increase in the number of canes. It seems probable that similar results would be obtained in other places, once it is determined in what direction the manurial constituents of

[1] Kilian, J. Bemestings-en plantverband-proeven op de S. F. Kanigoro, oogst 1908-9, *Archief v. d. Suikerind. in Ned. Ind.*, Vol. XVIII, p. 566, 1910.

the soil are lacking. Kilian's results on the numbers of canes are summarized in the following table :—

Numbers of canes per bouw ($1\frac{3}{4}$ acres) with different manures.

EXPERIMENTS WITH SUPER AND CATTLE MANURE: *Black Cheribon*					EXPERIMENTS WITH SULPHATE OF AMMONIA AND CATTLE MANURE ON DRY LOAM		
Manure	Thin dry loam	Dry loam	Heavy black clay		Manure	*J. 247*	*Cheribon*
4 pik. sulph. am. ...	33,011 slight fall*	38,261	28,772		3 pik. sulph. am.	57,135 irre-gular	34,559 irre-gular
do. +1 pik. super.					4 do.		
do. +2 do.	36,045 rise		34,367 slight rise	39,204 irre-gular	5 do.		
do. +3 do.		40,562			6 do.		
do. + cattle manure	37,698		36,642	42,865	4 do. + cattle manure	60,934	35,177

* The words "slight fall," "rise," etc., below an average figure, indicate any changes within the bracketed treatments.

Kobus[1] in an earlier paper (1905) describes the results of his experiments on growing cane uninterruptedly on the same land for a succession of years, with a various assortment of manures designed to take the place of rotation and fallowing. In this series were N, N and P, N and K, N, K and P, and all these with or without the previous addition of Ca. The series is a very full one, as it deals with three different varieties of cane, *J. 247*, *J. 33a* and *J. 36*. He states that the plots were much affected by the weather, there being a severe drought in the earlier part of the season, but that they recovered much better than he had expected. There were, however, many failures in germination, varying from 6·4 per cent. to 12·4 per cent. in the different varieties. Rats invaded the plots and created great havoc, to an extent in some cases of 40 per cent. Lastly, *J. 36* suffered from red rot, as this variety is more liable to the disease than the others. Among other data, he obtained the number of canes in each plot, and his general conclusions were that tillering is comparatively unaffected by manuring. By this we presume that he means rather that the *kind of artificial manure applied*, whether nitrogen, potassium, phosphorus or calcium in their various combinations, has little effect on the number of canes produced per acre. This does not seem to be quite the same

[1] Kobus, J. D. Cultuur van suikerriet zonder tusschen-gewassen. *Archief* v. d. *Java, Suikerind.*, Vol. XIII, 1905, p. 485.

position as that taken up by Kilian and, for the present, his more special work seems to be more to the point, as it deals rather with the quantity of suitable manure than the kind of manure applied.

Strüben,[1] in 1911, asserts that there appear to be no definite experiments on the effect of manuring on tillering. This seems rather strange, in view of his later quoting from both Kobus and Kilian. He states that he has often noted that very heavy manuring does not usually increase the number of canes. His general conclusion is that manuring does not affect tillering, although he does not himself experiment in the matter. As we have pointed out above, Strüben assumes the attitude that no appreciable alteration is made in tillering by various changes in cultivation, whether spacing, earthing up or manuring, and for this dictum he seems to depend on a generalization of Kobus, made in his 1905 paper, referred to above, that "with a difference of even 10 per cent. in the numbers of canes in a plot, there *may* be a similar out-turn of sugar at crop time." This perhaps will throw light on Strüben's attitude and, when he asserts that the number of canes is not influenced by manuring, he may mean that, as far as total sugar obtained is concerned, such differences as are noticeable are of little consequence. With this aspect we are at present not concerned, and have little hesitation in concluding that manuring has an influence on tillering, as well as any other means by which the healthiness and vigour of the plant is enhanced.

(6) Literature concerning the effect of spacing on tillering and on other crop characters.

The most obvious way of regulating the number of canes produced at harvest time is by varying the number of sets planted per acre. Spacing experiments have been conducted wherever the sugarcane has been cultivated, for the seed material, in many cases obtained by cutting up canes perfectly fitted for passing through the mill, costs a good deal and figures largely in the balance sheet. In some countries only tops are planted, namely, the upper, immature parts of the plant where there is no sugar, and the canes harvested produce these in sufficient numbers to plant up the new fields; but, in other places, tops are not available, as they form a valuable cattle food and, in India, for instance, are often the perquisite of the men from whom the cattle are hired for crushing the canes. We have already referred to the curious fact that, even in India, there are varieties which cannot be successfully

[1] Strüben, W. Uitstoeling. *Archief v. d. Suikerind. in Ned. Ind.*, Vol. XIX, Part 1, 1911, p. 487.

reproduced from the matured cane sets, but such exceptions are comparatively rare. When the Samalkota farm was started in the Godavari District, it was the local practice to plant 25,000 to 30,000 sets per acre, and the cultivators were quite content to put aside Rs. 30 to Rs. 40 for the purchase of seed per acre. A series of experiments was therefore initiated with the number of sets planted, varying from 4,000 to 30,000 per acre. The numbers of canes produced at harvest were counted and the amount of *jaggery* produced was estimated. These figures are now unfortunately lost, but the general conclusion arrived at was that, with proper treatment, each piece of land would produce the same weight of canes within comparatively wide limits, but that, when thick canes were sown at the rate of 12,000 sets to the acre, the maximum yield might be counted on, and that closer planting merely led to unnecessary expense in the purchase of sets. A similar series of experiments was made with *Reora of Benares* in Partabgarh in North India,[1] varying numbers of sets being planted per acre and the resulting yield of *gur* compared. Here, too, 12,000 sets per acre were found to produce the most satisfactory results, and the larger number of sets usually planted by the ryots did not give any increased yield. At first it strikes one as rather curious that thick and thin varieties, with their greatly differing tillering power, would require the same amount of space for their best development. But it must be remembered that the number of buds per set was considerably greater in *Reora* because of its short-jointed character. The number of sets planted per acre on different farms in North India appears, however, to differ very considerably (*cf.* Table on p. 63*a*), and it is not known whether these numbers are the result of series of spacing experiments, such as those made at Samalkota and Partabgarh, or are merely an adoption of the local ryots' practice until such experiments can be conducted.

Stubbs[2] quotes a certain Mr. Skeete, who speaks of sets planted six feet apart, with the result that often 50–100 canes were reaped from one hole. We have been unable to verify this reference or to discover what country is spoken of, but it appears to be not at all unlikely, for Prinsen Geerligs[3] states, of San Domingo, in the West Indies, that the canes are occasionally planted nine feet apart each way, which would mean only 538 sets to the acre, and presumably the tillering in such cases would be great enough to make up the requisite number of canes at harvest time. It is the custom at the

[1] Clarke, Annett and Hussain, etc. Experiments on the cultivation of sugarcane at the Partabgarh Experimental Station, 1910-11. *Bulletin No. 27, Agr. Res. Inst., Pusa,* 1911.

[2] *Ibid,* p. 95.

[3] Geerligs, H. C. Prinsen. *The World's Cane Sugar Industry, Past and Pres.,* p. 193, 1912.

Cane-breeding Station to give the thick canes more room than the thin, in spite of their smaller tillering power, and this appears to be the general rule in India where these two types of canes are planted on the same farm. There is, however, a much more liberal application of manure in the former case, for the thin canes are found to be unable to assimilate such heavy dressings and, at the same time, to mature properly at harvest time. The object aimed at in each case is to obtain a full stand, with as great a weight of canes as possible, without unnecessary expenditure in costly seed material. The development of the cane clump is influenced by warmth, moisture, soil, and no strict rule can be laid down as to the most suitable spacing, and hence the importance of the very numerous experiments which have been made.

Several workers have dealt fairly fully with the relation between spacing and the number of canes reaped, and it will be necessary to consider their papers somewhat in detail. As other matters, besides the influence on tillering, are also included in them, it will be convenient to treat these papers as a whole, and append a summary of conclusions at the end under the several headings.

Stubbs, in 1892-93, conducted experiments with the local Louisiana canes by planting the sets at distances of 6″, 12″ and 18″ in rows five feet apart. The plants were first reared in a nursery and, as each was planted in its plot, care was taken that it was the result of the growth of only one bud. His results are given in the following table :—

Spacing	Number planted in March	Shoots in June	Shoots in October (harvest)	Average weight of each cane	Tonnage
6″	17,600	72,325	39,050	2·17 lb.	42·55
12″	8,800	51,188	32,964	2·49 lb.	41·60
18″	5,860	37,230	29,070	2·60 lb.	37·24

These figures show a greater number of shoots arising in the more closely planted rows, but a gradual diminution of the differences in these numbers as growth proceeded. Inversely, there was an increasing weight of individual canes with greater spacing, but the tonnage was greater in the closely planted plots. Stubbs concluded that tillering depends on room available, and that there is practically no limit to it, provided the space given is sufficiently ample. In 1894-95 he carried out the same experiment with much greater care, studying each plant throughout its growth. Five plants of each of the two varieties, the *Striped* and the *Purple*, were used in each experiment, so that, altogether, there were thirty plants. A book was kept of births and deaths by the chemist in charge, who also labelled each shoot as it appeared. At harvest each clump

was dug up and the labels examined, the parent stalks were marked and their relation to their branches ; each cane was separately weighed and analysed. It is impossible to conceive of a more strictly scientific method, and the results are well worth study, especially as the conclusions arrived at are at variance in some respects with those of others to be referred to below. More shoots started with the wider spacing, but the ultimate number at harvest was practically the same. In the chemical analysis of the canes, the main stem had the richer juice and the author claims a gradual decrease in weight and sucrose in successively developed branches. He admits, however, that three canes behaved in a contrary manner, and we shall refer to these below. It is especially with regard to the decreasing richness of juice that other workers disagree with Stubbs and, from the following considerations, it seems to us that the author was scarcely justified in drawing the conclusions that he did. We have not been able to study his original paper, but there are sufficient details given in his book on the sugarcane for our purpose. At the same time attention may be drawn to the extraordinary inaccuracies in the general averages of all the canes, especially in the first table on page 132. There were 139 canes instead of 132 as quoted, and the general averages of Brix and sucrose are obviously wrong, suggesting a whole series of printer's errors more than anything else.

From a careful analysis of the tables, we gather that the crops grown in the two years differed widely. In 1894, 20 parent plants produced 139 canes at harvest, whereas, in 1895, there were only 131 from 29 plants. The sucrose was higher in 1894, and the glucose was much lower. From this it appears that the twenty 1894 plants had more space for development and that they were better matured than the 29 in 1895. A reference to the temperature and rainfall during these two years, fortunately given in chapter V of the book, indicates that this difference was due to the character of the growing seasons. That of 1894 was favourable to the production of good, well matured crops, while that of 1895 was altogether unfavourable, especially because of the excessive rains of May 22–24, when over six inches fell, which checked growth and rendered the important late cultivation of the ground impossible, this being followed by a drought which was equally disastrous. In 1894, with the better growing weather, only one cane was reaped which commenced its growth after July 2 ; in the 1895 crop 7 out of the 11 classes of canes commenced their growth after July 6, and some arose as late as September. When we remember the author's dictum that " in normal weather, only shoots developed up to July may produce a good stand," we can without difficulty conclude that the 1895 crop, being immature, was not a suitable one on which to found generalizations regarding the relative sucrose contents

of the canes of different ages. The sucrose does, it is true, show a regular decline in the later formed shoots, but this is exactly what would be expected from their increasing immaturity. When, on the other hand, we analyse the figures given for the healthy, well matured 1894 crop, it is not easy to follow the author's conclusions. The average weight of the twenty parents was 2·01 lb. while that of the 119 branches was 2·03 lb. Among the latter, 89 shoots, developed during May and June, weighed on the average 1·97 lb., while the thirty later ones, developed in June and July, averaged 2·22 lb. These figures, indeed, rather point to an increase in weight in the later formed canes. As to sucrose, the 20 parents averaged 13·42 per cent., the 89 of May and June 12·27 per cent., and the 30 of June and July 12·47 per cent. Here there is a marked difference between parent and branches, but no fall in the sugar content of the branches during the season, as claimed by the author. There are two canes, however, at the end of the series, which stand out as heavy, and three with high sucrose content; Stubbs draws attention to these, as exceptions, without being able to explain their meaning. It is possible, with our experience in stool dissections, to throw some light, at any rate, on the two heavy ones.

From the details given by the author on the branching of one plant, we can, without difficulty, reconstruct the scheme of its branching. There were five mature canes and 12 shoots of 5-6 feet in length, whose distribution is given in detail, and the reconstruction is given in Figure 1. This distribution is in general agreement with what we should expect in the branching of a thick cane in the time. Starting with this as a basis, we are also able to build up average schemes for the matured canes of the 1894 and 1895 crops, since the relative numbers of parents and branches are given in the tables. These are given in Figures 2 and 3 for 1894 and in Figures 4 and 5 for 1895.

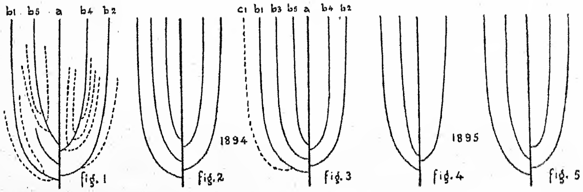


fig. 1 fig. 2 fig. 3 fig. 4 fig. 5

The two exceptional canes in 1894 crop were produced at the end of the branching season (June-July) and were considerably heavier than those

immediately preceding them. The change is rather a sudden one. We shall see, in our dissections, that, in any system of branching, while the *a*s or main shoots do not differ very greatly from the *b*s or branches of the first order, there is usually a more marked difference between these two and the *c*s, the latter being generally considerably thicker. It appears to us that, with the favourable season of 1894, it is probable that in some of the 20 plants a branch of the second order may have matured; while it is highly improbable that any of the 1895 shoots of the same order would be sufficiently advanced to be cut as canes at crop time. In this case we should have, among the 1894 plants, at least two which had a *c* branch matured, as is suggested in Fig. 3 of the diagram, and this would explain the presence of these abnormally heavy canes at the end of the season (*cf.* Pl. XXXII, where diagrams of thick cane branching are shown, and Table on p. 147, where the formulæ of *Louisiana Striped* and *Louisiana Purple*, grown in the Cane-breeding Station, are given).

We think that Stubbs is justified, from his figures, in assuming that, in the Louisiana climate, the mother shoots are at harvest richer than the branches, but we do not think that his facts are sufficiently convincing to assume the regular decrease in sucrose among the younger shoots, excepting where they are also increasingly immature, as in the 1895 crop. We also do not agree with him in his contention that his figures give ground for the assumption that there is a gradual decrease in the weight of branches in the order of development, as it runs counter to all our experience in the dissections which we have carried out, and is not borne out by the figures in his tables. Stubbs's paper is of special interest to us, in that it is the only one we have met with in which any care has been taken to separate the branches of different orders.

The next pieces of work on the effect of spacing on the number of canes produced are in 1910, when independent experiments were conducted by Kilian and Muller von Czernicki in Java. Kilian's experiments[1] were made, with *J. 247*, a late but good tillering variety, on dry loam, "strugge[2]" loam and heavy black clay. It is unfortunate that the control plot of the latter was destroyed by fire; this class of soil, namely heavy clay, is apparently less suited to *J. 247*, and the results recorded of the single experiment show that some unmentioned factor has intervened. This plot we have accordingly left out in the discussion, and confined our attention to the four others, on loam of varying fertility. Kilian planted his sets in rows $3\frac{1}{2}'$, $4'$ and $5'$ apart, and a summary of his results is given in the appended table, averaging the duplicate plots.

[1] Geerligs, H. C. Prinsen. *The World's Cane Sugar Industry, Past and Pres.*, p. 193, 1912.

[2] We have been unable to translate this word, but imagine that this loam is less fertile.

Spacing of rows		Number of canes reaped per bouw	Weight of canes per bouw in pikuls	Weight of sugar obtained per bouw in pikuls	Sucrose per cent. in the juice
Dry loam ...	3½′	65,089	2,070	197	13·76
	4′	62,771	2,056	201	14·06
	5′	59,163	1,978	199	14·33
"Strugge" loam ...	3½′	55,135	2,092	210	14·40
	4′	54,175	2,023	206	14·58
	5′	50,388	1,946	201	14·81
Heavy black clay (no control)	3½′	40,907	1,633	162	14·23
	4′	48,277	1,745	181	14·60
	5′	40,038	1,536	158	14·75

From this table it is seen that the number of canes harvested decreases regularly with the increased width of the rows ; the total weight of cane varies in the same sense within narrower limits, suggesting that, with wider spacing, the canes are on the average heavier. The quantity of sugar obtained varies irregularly, the advantage in one case being on the side of closer planting ; the sucrose in the juice, however, is interesting, in that there is a uniform rise as the rows are wider apart, and in this respect the aberrant third experiment falls into line, suggesting again that the thicker canes have richer juice. No reference seems to be made by Kilian to this rise in sucrose with wider spacing, but it agrees with the generalization of Kobus and van der Stok that, in the same plot, the thicker canes have richer juice.[1] Kilian is perfectly justified in drawing the conclusion that the results do not point to any advantage in altering the four-foot rows which appear to be most usual in Java.

Muller von Czernicki's[2] experiments were on a much larger scale, and extended over several years. His work is the most important contribution which we have met with on the effect of spacing on tillering, and the number of canes reaped, and deserves careful study. He had noted great variation in the spacing on different estates, without being able to find any reasoned justification for the local practices. For himself, on his Poerwodadi estates, it was a matter of considerable importance how many sets were used per acre, as much of the seed had to be imported and was expensive. He accordingly laid down a series of experiments to determine if equally good results could be obtained with a sparser sowing. He also wished to determine the relative tillering power of the different varieties and the time at which the maximum number of

[1] J. E. van der Stok, in Früwirth's *Die Züchtung der Landwirth-schaftlichen Kulturflanzen, Zuckerrohr.*

[2] Muller von Czernicki, C. F. Proefnemingen omtrent Plantwijdte. *Archief* v. d. *Suikerind. in Ned. Ind.*, Vol. XVIII, 1910, p. 314.

shoots was reached. At first he dealt with very large areas, planting them with rows 4 and 5 feet apart. There appeared to be no increase in the number of canes with the wider spacing, rather the reverse, and he decided to concentrate on varying the distance of the plants in the rows. But, in this case also, the results were inconclusive, and this he put down to the varying soil conditions and the impossibility of planting control plots in such large experiments. He therefore instituted a number of experiments on plots one-tenth of a bouw in area (practically 17 tenths of an acre or, as it is termed in Madras, 17 cents). The rows were, as usual, 4 feet apart and about 30 feet long. In these he planted *Black Cheribon, J. 247* and *J. 100*, varieties which were of importance in his area. The sets were planted 10, 12, 14, 16, 18, and 20 to the row. Countings were made of the shoots above ground at 60, 90, 120 and 150 days from sowing, which, presumably, roughly coincided with the different earthings up ; and, 14 days after the last counting of shoots, he counted the canes formed, with a convention which seems to hold in Java of taking two or even three thin canes as the equivalent of one thick one. Muller von Czernicki complains repeatedly of the depredations of thieves and other injuries in his small plots ; the presence of *sereh* is also commented on in the plots planted with locally raised seed, but these injuries are of less moment in the early countings, in which we are most interested here, than in the final crop. Numerous tables and graphs illustrate his paper and of these one table and two graphs are reproduced, as the paper is in Dutch and not easily available. In the table one notes with surprise the very early general development of branches from the sets, a steady decline usually following, after the first couple of months. Muller von Czernicki concludes as follows with regard to the three varieties tested :—

The number of shoots counted at different periods, with sets planted at different distances apart—Muller von Czernicki.

1908 *crop.*

Number of sets planted per row	Number of plots averaged	NUMBER OF SHOOTS COUNTED AT					Crop in pikuls per bouw ($1\frac{3}{4}$ acres)	Sucrose % in the juice
		1st earthing up	2nd earthing up	3rd earthing up	Last earthing up	After the last earthing up		
		Generatie Cheribon						
10		124	122	103	77	61	1,398	15·6
12		138	131	108	77	62	1,416	
14	10	155	147	118	81	66	1,416	
16		178	162	125	85	67	1,404	
18		167	160	124	85	68	1,386	
20		180	170	130	88	72	1,518	15·8

The number of shoots counted at different periods, with sets planted at different distances apart—Muller von Czernicki.

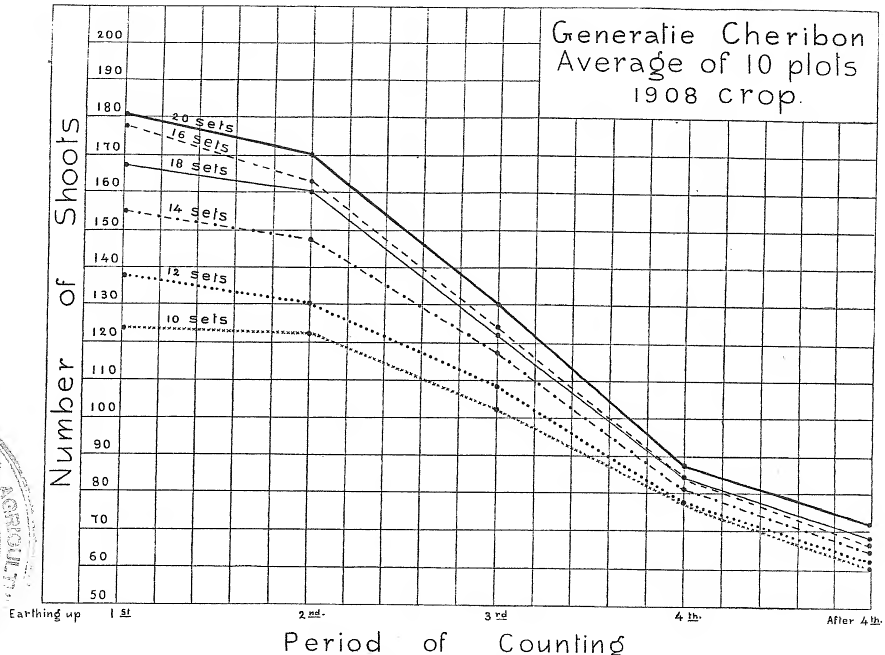
1908 *crop*—concld.

Number of sets planted per row	Number of plots averaged	Number of shoots counted at: 1st earthing up	2nd earthing up	3rd earthing up	Last earthing up	After the last earthing up	Crop in pikuls per bouw (1¾ acres)	Sucrose % in the juice
Plantriet No. 247								
10	8	120	150	159	114	95	1,728	12·7
12		143	170	166	114	92	1,554	
14		153	175	167	115	92	1,452	
16		165	187	173	117	96	1,530	
18		180	196	180	119	97	1,506	
20		190	212	192	122	100	1,536	13·5
Generatie No. 247								
10	28	161	168	148	122	101	1,536	13·5
12		191	178	155	122	98	1,422	
14		203	188	154	120	95	1,416	
16		224	192	160	122	90	1,416	
18		232	202	160	122	95	1,446	
20		240	206	160	124	96	1,410	13·5
Generatie No. 100								
10	3	98	128	124	100	82	1,140	16·7
12		124	140	124	101	83	1,200	
14		127	148	123	104	83	1,220	
16		142	150	128	104	83	1,220	
18		157	146	126	106	86	1,320	
20		168	156	124	106	86	1,320	15·6

Cheribon has the greatest number of shoots at 60 days, that is at the first counting; in the rows with ten sets the maximum is a little later, but at 150 days from sowing all the plots are approximately equal.

J. 247 tillers more slowly. When planted from sets, the maximum occurs at 90 days, and, in the 10 sets plot, at 120; when planted from tops, because presumably of the greater number of buds, the course of events is practically as in *Cheribon*.

J. 100 (of which only three plots were planted) reached its maximum number of shoots early, the plots with 18–20 sets at 60 days and the rest at 90 days, and after that period there was little difference in the plots.



Shoot-counting table, copied from Muller von Czernicki.

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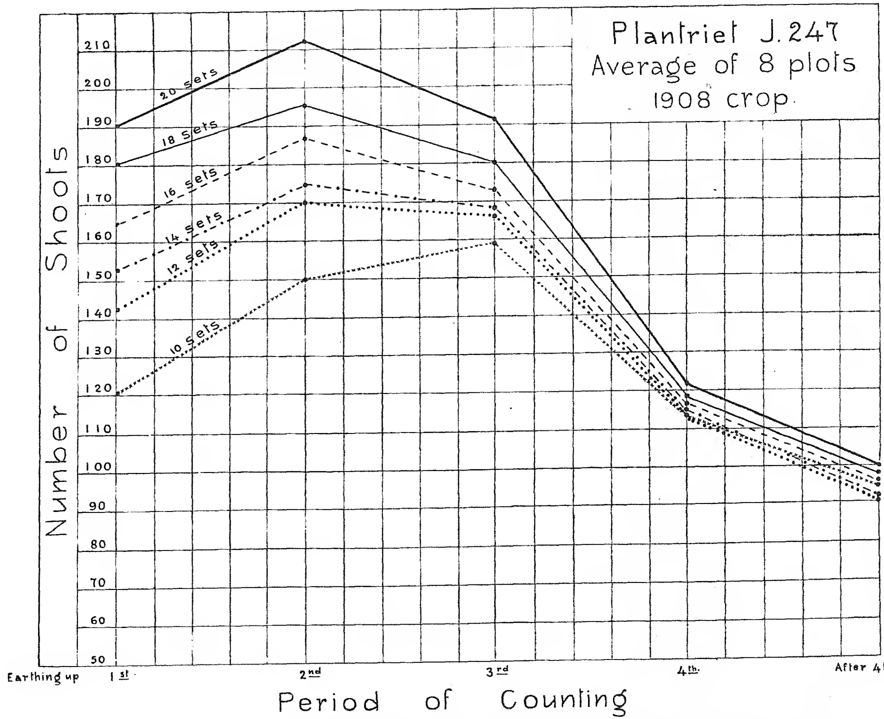


Shoot-counting table, copied from Muller von Czernicki.

An inspection of the table and graphs will convince the reader of the greater tillering power of the widely spaced plants, where of course there were considerably fewer plants to the row, and the subsequent great mortality of shoots which soon reduced the numbers, till they were more or less uniform in all the rows—all the available light being used up.

The author draws the following conclusions regarding the possibility of reducing the number of sets planted per acre. This is of special importance with the costly imported material, and he points out that, with *Cheribon* and *J. 100*, it can be substantially diminished with safety. This also applied more or less to locally grown seed, but the danger of *sereh* is greater and the cost of the seed is much less, so that no change is suggested.

The experiments were repeated in 1909, with 8–20 sets per row, as it seemed to Muller von Czernicki that the lower limits of sowing had not been reached. The results confirmed those of the previous year. In *J. 100*, owing to a mistake, there was only one plot, but in the row with 8 sets a full stand was easily reached.

Muller von Czernicki makes certain observations as to the sucrose content of the mother cane and its branches. He states that some people seem to believe that the mother canes are richer than those developed later, but he cannot find any grounds for this belief. "After many years of observation," he has come to the conclusion that, provided that canes are ripe, there is little or no difference in this respect. He points out that the definition of mother shoot is a very loose one, and quotes Hovenkamp as saying that "mother canes need not be primary stems, but are the thicker and richer canes." We see elsewhere that the assumption is unwarranted, in that the canes of the third order of branching are almost always thicker than the mother canes. And we fail to see in what respect Muller von Czernicki's own deductions are more accurate, in that there are no references to stool dissections, and, without these, it is practically impossible to decide which the mother canes are. He, however, approaches the matter from another point of view. With closely planted sets, there will, he argues, naturally be more mother canes than in widely spaced rows, and this must make its influence felt, if there is richer juice in them, than in the branches; but he has not been able to detect any such difference. Muller von Czernicki's deduction would appear at first sight to be perfectly sound, but he does not go far enough. There will certainly be fewer *a*s in wider pacing, but we do not know whether the relative increase in the numbers of branches of the lower orders is in the *b*s, *c*s, or possibly *d*s. Again, in closer planting, there will be a greater proportion of *a*s in the canes

reaped, but here also we are in the dark as to whether this is accompanied by a diminution of the relative numbers of *c*s and *d*s, which might give the *b*s a predominance over them. This side of the question is of some importance, for we shall see later that, while the *a*s and *b*s are often very similar, the *c*s and *d*s differ radically from them, and the question is thus not only influenced by the relative number of *a*s in the plots, but also whether the *a*s and *b*s on the one hand or the *c*s and *d*s on the other are in relative excess. Until we have more definite information on these points, we should prefer to rely on the actual analyses of early and late canes as given by Stubbs and carried out for some years on the Cane-breeding Station at Coimbatore; but these latter will be referred to later.

Muller von Czernicki states that he has often noted the differences in thickness of canes sparsely and closely planted, especially in the 1909 experiments, and he decided to test this more carefully. He therefore measured 50 canes from each plot in the following manner, making altogether 1,000 measurements. He used a pair of calipers which he moved round the stem until it encountered the greatest resistance, and took the measurements at about one metre from the ground at the middle of an internode. His results are given in a series of tables, in which the canes are arranged according to their thickness in each plot, with differences in millimetres. From these measurements in thickness he deduced the weight of the canes. By using a formula he calculated the difference in average weight of canes in the rows with 8 and 18 sets, the extremes of the series. This difference varied from 10·5 per cent. in imported *Cheribon* sets, to 17·6 per cent. in local *J. 247*. The average of these differences in the four kinds of seed used was 14 per cent., which means that 86 canes in the thinly sown rows would equal in weight 100 in the closer planted rows. In these deductions he assumes that the plants in the different rows were of equal height, but he himself observes that this was by no means the case; he therefore concludes that for accurate determinations of the weights of individual canes direct weighings will alone suffice.

Strüben, in his paper on Tillering (1911), already mentioned, collates numerous countings of canes made by different workers, under the most varying conditions of climate, soil and treatment, and concludes that, within narrow limits, each variety shows the same cane-producing capacity, limits narrow enough not to be of appreciable influence from the crop point of view. He further gives the results of a series of experiments conducted by himself on the lines laid down by Muller von Czernicki. He experimented with *J. 247* and placed 6, 8, 10, 12, 14, 16 and 20 sets in separate rows of the same length,

counting the canes at harvest in each case. The following table summarizes his results :—

Canes reaped at harvest.

Sets per row	*J. 100* : heavy clay		*Cheribon* : fertile land		*Cheribon* : infertile land	
6	74	85	63	68	65	70
8	76	89	69	70	75	80
10	82	89	70	72	82	84
12	85	92	69	76	85	86
14	91	86	72	76	86	85
16	95	86	71	76	86	84
20	94		72	74		

Looking at the figures as a whole, there is a general rise in the number of canes, at first rapid and then slow, as the number of sets per row increases ; but this rise appears to receive a check when 12–14 sets per row are reached, and after this there is usually equality or even a slight decline. In only two cases of the six is there anything like a general rise throughout. But the counting of fully formed canes is not a true measure of tillering power, and Strüben's figures do not help us in this respect to the same extent as do those of Muller von Czernicki.

The question of tillering power of the canes in the field, and the effect of this upon the harvest, is thus seen to be somewhat complicated. The number of canes reaped at harvest is connected with the tillering power, but this connection is obscured by the great mortality of shoots during the growth of the plants and is therefore less close than might be expected. Similarly with the weight of canes at harvest ; the weight of individual canes in the clump probably varies according to the date of appearance, and the average weight of canes varies with the closeness of planting and the corresponding number of total canes produced. The total yield of sugar depends upon the weight of the individual canes, their number and the richness of the juice. There is some evidence that the amount of sugar in the juice differs in branches of different orders. Spacing the planting material has its influence on all these factors, and it may be useful to summarize the views of the different writers already quoted, and to add such observations on the subject as have been accumulated from time to time on the Cane-breeding Station. The subject will be treated in the following order :—The effect of spacing on the tillering power, as judged by the number of shoots produced per clump, and by the number of canes produced per clump at harvest : on the thickness and weight of the individual canes and the total weight of canes reaped : on the total yield of sugar in the

crop. A note will then be added on the richness of the juice in branches of different orders in the clump.

(a) *Effect of spacing on tillering as judged by the number of shoots produced per clump.* Stubbs, in 1892-93, showed that, by planting the sets at 6″, 12″ and 18″ apart, the number of shoots produced differed a good deal. At three months after planting the 6″ plants had, on the average, 4·1 shoots each, those at 12″ had 5·8 shoots, while those at 18″ had 6·4 shoots per plant. Observations have not as yet been made on this point at the Cane-breeding Station. The following figures have been deduced from those published by Muller von Czernicki and referred to above. We have obtained them by dividing the maximum number of shoots in his countings by the number of sets in the row. The cases selected are the extremes and an intermediate one, namely, where sets were planted 10, 14 and 20 in the row. The following are the maximum numbers of shoots for these spacings: *Cheribon* (tops), 12·4, 11·1 and 9·0; *J. 100* (tops), 12·5, 10·6, 8·4; *J. 247* (tops), 16·8, 14·5 and 12·0; *J. 247* (sets), 15·9, 12·5, and 10·6. The extreme differences in these spacings are roughly as 3 to 2 shoots per plant for the wider plantings.

(b) *Effect of spacing on the total number of canes per clump at harvest.* We are able to get more cases in which this has been observed, in that countings of canes at harvest appear to have been made regularly for many years in Java. Stubbs gives the figures for the canes at crop time (seven months from planting), in Louisiana, and from these we find that the number of canes per clump at 6″ is 2·2, at 12″, 3·7 and at 18″, 4·9. Comparing these figures with those in section (a) we see that, although a number of shoots had died, the ultimate differences had increased.

Kilian gives the number of canes at harvest per bouw (1·75 acres) when the rows were 3½′, 4′ and 5′ apart, and we can obtain proportional figures for the number of canes per clump by multiplying these two sets of figures together. It is to be noted that the differences in spacing were not nearly so great as in Stubbs' experiments, but the results are still very definite. Taking the table given on p. 82, we get the proportional numbers as 4·6, 5·0 and 5·9 canes per clump in the richer land and 3·9, 4·3 and 5·0 in the poorer.

Muller von Czernicki does not give the numbers of canes at harvest, but counts them at 5-6 months, using the Java convention of taking two or three thin canes to one thick. Selecting the rows as before with 10, 14 and 20 sets, we get the following figures:—

Cheribon (tops), 6·1, 4·7 and 3·6; *J. 100* (tops), 8·2, 5·9 and 4·3; *J. 247* (tops), 10·1, 6·8 and 4·8; *J. 247* (sets), 9·5, 6·6 and 5·0. Here again there is an

increase in the differences in the numbers of shoots produced per plant as the period of harvest approaches, which is not to be wondered at, as the effect of the spacing should be cumulative throughout the growth of the plant.

The same author conducted spacing experiments on a very large scale, the plots extending over 100 bouws (175 acres) with sets planted roughly as 2 to 3 for the same space. This again is a smaller difference in space allowance than Stubbs's, but the results are obvious enough. The numbers of canes per bouw are practically equal, showing that the effect of the spacing was that each clump, on the average, produced half as many canes again in the wider planting.

Wider spacing thus has a marked influence on the maximum number of shoots developed per plant; this effect is cumulative, during the period of growth, and is therefore intensified at the time of harvest.

(*c*) *Effect of spacing on the thickness or weight of the individual cane.* Stubbs gives the average weight of cane when the sets were planted 18″, 12″ and 6″ apart, in lb. as 2·60, 2·49 and 2·17. Kilian's results are less conclusive, but the distances apart in the 3½′, 4′ and 5′ rows were very much less. The relative weights in the two tables were as 3·2 to 3·3 to 3·35 and 3·8 to 3·75 to 3·85. There is thus practically no difference in the weights of the canes. Muller von Czernicki dealt rather carefully with the thickness of the cane, and he deduced the weights on the assumption that the canes were of equal height (which he states from observation is not perfectly correct). He measured the canes at 5-6 months with calipers, in the rows with 8 and 18 sets in them. The result that he obtained from a large number of plots was that the canes in the 8 sets plots were 14 per cent. heavier than those of the 18 sets plots. Other observers, notably Kobus and Van der Stok, emphasize the fact that wider spacing increases the thickness of the individual canes, and it may be considered therefore as incontestible.

(*d*) *Effect of spacing on total weight of canes at harvest.* A wider spacing therefore produces more canes per plant, and these are thicker and heavier. But there are fewer of these plants to the acre. Stubbs gives figures for the total weight of canes reaped, with his spacing of 18″, 12″ and 6″ in the row, as 37·24, 41·6 and 42·55 tons per acre, a distinct though small advantage for the closer planting. Kilian's figures agree, taking the smaller differences into account in his spacing experiments. The total weights of canes in the 3½′, 4′ and 5′ rows were, in pikuls per bouw, 2070, 2056 and 1978 respectively.

Muller von Czernicki in his larger plots of 3–5 acres obtained "no advantage in yield by planting widely (5′ instead of the usual 4′), rather the reverse," but the experiments he considered unsatisfactory because of variations in soil and the impossibility of having any controls. In his carefully controlled smaller plots, again selecting the rows with 10, 14 and 20 sets in them, he gives the following weights of canes reaped in pikuls per bouw, *Cheribon* (tops), 1398, 1416, 1518; *J. 100* (tops), 1140, 1220 and 1320; *J. 247* (tops), 1536, 1446 and 1410; *J. 247* (sets), 1728, 1452 and 1536, respectively. These figures are in favour of closer planting in the *Cheribon* and *J. 100* plots but in the *J. 247* they are inconclusive, and in fact have higher yields in both cases with the wider planting (Has this anything to do with the known greater tillering power of this variety ?).

On the whole, there seems to be a general concensus of opinion that wide planting reduces the yield in canes at harvest and the best distance apart will have to be decided for each variety, climate and soil as the result of experiments on the spot. With the generally higher yields of closer planting, it becomes a matter for the balance-sheet, especially where the sets are costly, for the price of the latter may then easily exceed the advantage gained by planting more sets to the acre, as was the case in the Samalkota tract referred to above.

(*e*) *The influence of spacing on total yield of sugar.* The factors of moment in the yield of sugar per acre are very numerous. The variety grown, the climate and soil, the character of cultivation, the efficiency of the manufacturing side, the number of canes per acre and their thickness, and the richness and quantity of juice, are all concerned. It is difficult to quote experiments where the effect of all these factors have been considered, but the various workers have given their opinions and these may be summarized, in that they are in general agreement. Within fairly wide limits, close planting appears to give a greater yield, but this is chiefly where the general level of cultivation is low. The local rate of planting is, in India, frequently excessive. This was clearly shown at Samalkota where the same yield in *jaggery* was uniformly obtained with thick canes by planting half the sets generally used. Similar results were obtained as to the maximum yield of *gur* in the experiments at Partabgarh, where, however, only one local cane was experimented with and that of course was a thin indigenous one. A somewhat similar result appears to have been obtained by Stubbs in Louisiana, for he recommends for the maximum crop the planting of the sets 6″ apart in 5′ to 6′ rows.

As to Java, Kobus lays it down as the result of his observations and experiments that even a difference of 10 per cent. in the number of canes per acre may very well go with the same yield of sugar. From this, we gather that the number of canes, which we have seen to be influenced by spacing, is not too closely connected with the yield of sugar, and therefore that the effect of spacing is of little import within moderate limits. This statement of Kobus is taken up by Strüben, who argues in its favour and states that the Editor of the *Archief*, the principal organ of the Java industry, has long held the same view. Kilian's experiment of planting canes in rows, $3\frac{1}{2}$,′ 4′ and 5′ apart, gave results from which he gathers that, in *J. 247*, the current distance of 4′ cannot be altered with advantage. In the two controlled experiments on dry loam, the yields of sugar in pikuls per bouw for these spacings were respectively 197, 201, 199 and 210, 206 and 201; while another uncontrolled experiment on heavy black clay gave 162, 181, 158. Muller von Czernicki found, in crop experiments of 3 to 4 acres each over 175 acres, that a spacing varying as 2 : 3 made practically no difference as to yield of sugar. We may therefore conclude, that, with good cultivation, the yield of sugar, influenced as it is by so many factors, has no intimate relation to the spacing of the plants, and that this may accordingly vary within moderately wide limits without disadvantage. These limits have to be determined in each place and with each variety separately.

(7) Note on the relative richness of the juice in branches of different orders.

Kobus has made an oft-repeated generalization, after years of experiment, that, in a cane field, "thicker clumps have heavier canes and richer juice." Van der Stok also asserts that, in a general crop, the thick canes have more sugar in their juice.[1] Stubbs showed that, in the Louisiana crops, the mother canes had richer juice than the branches from it, but he failed to convince us that the earlier branches also had better juice than the later. In Java, writers generally take exception to this imputed superiority of the mother canes, and Muller von Czernicki asserts his conviction that, provided the crop ripens, as it generally does there, there is no difference in the juice of the different orders of branching. This rather discounts the Louisiana results, for a crop reaped at seven months from planting can hardly be considered by cane growers in the tropics as properly matured. But, on the other hand, we have failed to

[1] J. E. Vander Stok, in Früwirth's *Die züchtung der Landwirth-schaftlichen Kultur-flanzen Zuckerrohr*

discover any indication that the true character of the branches has been determined in Java. After a good many dissections, we conclude that it would be a very difficult thing, without experience thus gained, to detect which are the mother canes of the crop. There seems, in general, to be a tendency to assume that these are thicker than the rest, but our results are exactly the opposite, as will be seen in the sequel (Part III, section 6). We cannot therefore think that the opinions on this point either in Louisiana or in Java are altogether trustworthy.

A certain amount of work has been done at various times in the Laboratory of the Cane-breeding Station, on the richness of the juice in the different canes in the clump during growth and at crop time. In our study of early and late canes, we made use of the members of the Pansahi group, because, before we had made our dissections, it was easy to distinguish between the early and late canes. Some of the results of this study have been given in Memoir II (p. 159), where it is shown that, in several varieties (*Maneria*, *Kahu*, *Yuba* and *Pansahi*), it was easy to separate the different classes of branches at crop time, and that, in their analysis, the earlier formed canes were invariably richer in their juice than the later. At the close of the 1917-18 crop, an attempt was made to divide the cut canes into classes, by observing the characters by which the branches of different orders could be separated, starting with thickness of cane and, where necessary, introducing length of basal part, average length of lower joints, curvature, etc. This separation was, as usual, found to be specially easy in the members of the Pansahi group. One hundred canes were thus dealt with in each of the varieties dissected and these were divided into their appropriate classes and separately analysed. The results obtained in the members of the Pansahi group are given in the table, and we see that they agree quite well with those given in the previous Memoir. In *Maneria*, the percentage of sucrose in the different classes from earliest to latest was 14·25, 13·74, 13·63, 13·57, 9·80, and in *Yuba* 15·17, 14·86, 13·14, 12·53 and 12·40.

Relative richness of juice at harvest in different classes of canes in the Pansahi group.

Variety and number of plot on the farm	Class of cane	Number of canes	Character of cane	Average thickness of cane in cm.	Brix	Sucrose	REMARKS
Maneria 2716 ...	1	10	very early	1·60	16·90	14·25	The tops were not withered. There was a continued reduction in sucrose content as we passed from early to late canes.
	2	10	early	1·60	16·40	13·74	
	3	19	,,	1·95	16·40	13·63	
	4	28	,,	2·15	16·48	13·57	
	5	16	late (rather immature)	2·25	13·99	9·80	
	6	17	immature	not analysed			
Yuba 2710 ...	1	6	very early	1·55	17·81	15·17	The tops were slightly drying up, but in spite of this the analyses show the same course as in Maneria.
	2	25	early	1·60	17·77	14·86	
	3	24	,,	1·75	17·17	13·14	
	4	20	late	1·45	16·13	12·53	
	5	12	later	2·30	16·13	12·40	
	6	13	immature	not analysed			
Chynia 2711 ...	1	7	very early	1·70	15·30	12·07	Tops dried. This appears to have affected the richness of juice detrimentally in the very early canes. The remaining analyses are as in Maneria and Yuba.
	2	22	early	1·70	17·11	14·34	
	3	36	,,	1·90	16·94	13·75	
	4	14	later than 3	1·80	15·43	12·00	
	5	15	distinctly late	2·20	15·50	11·71	
	6	6	immature	not analysed			
Kahu 2713 ...	1	26	very early	1·60	15·02	12·03	Tops dried. Analyses as in Chynia.
	2	33	early	1·70	16·12	13·10	
	3	28	,,	1·85	15·67	12·14	
	4	8	late	2·35	15·88	11·93	
	5	5	immature	not analysed			
Pansahi 2718 ...	1	10	very early	1·45	13·56	10·76	Tops dried. Analyses as in the last.
	2	26	early	1·65	15·88	13·12	
	3	30	,,	2·00	16·28	13·23	
	4	20	late	2·50	13·06	9·13	
	5	14	immature	not analysed			
Sada Khajee 2719...	1	9	very early	1·70	15·82	12·88	Tops dried. Analyses as in the last, excepting that the fourth class are a good deal the thinnest— possibly late poorly developed shoots.
	2	25	early	1·80	17·81	15·09	
	3	44	,,	1·95	17·44	14·49	
	4	9	,,	1·45	16·58	13·83	
	5	13	immature				

In the remaining members of the group the first formed canes had less sucrose than those immediately following, but this result is not surprising, in that in these varieties the first formed canes are marked as "dried up." We have, from the first, been accustomed to choose the Pansahi class for demonstration of any character which it was desired to emphasize, as there is something peculiarly regular in the growth of these canes, whether in the symmetry of the branching, the regularity with which the characters of the branches of

different orders are displayed or the variation in the sucrose from early to late formed canes; and we have recently discovered that a study of the joint curves of the Pansahi varieties shows that there is a well marked periodicity in the growth during the season.[1] But it is a question whether this almost mathematical regularity in growth is shared by other classes of indigenous canes or is merely a character of this strongly marked group. And the answer to this question is at present by no means easy to give.

A reference to Memoir II (p. 159) will show that, while it was easy to separate the Pansahi canes into classes, this was found to be next to impossible in the other varieties examined at the same time, *Ekar*, *Baroukha* and *Kaghzi*; also that, when the attempt had been made, there was no trace of the regular decrease in sucrose in the branches of succeeding orders. Assuming that it would be much easier, with our increased knowledge of the characters, to separate the *a*s, *b*s, *c*s, *d*s, etc., of each clump, all the other varieties which had been dissected were treated in the 1917-18 crop as were those of the Pansahi group. Unfortunately, in my absence, and through a misunderstanding, the work was not done until May, when most of the canes, at any rate the earlier ones, were overripe or withered. The members of the Pansahi class seem to have been little affected by this, but it may be the cause for the other varieties failing to show any regularity in the richness of the canes of different orders of branching. On a study of the results of analysis, the figures are so irregular that no object would be attained by their reproduction here, and they are merely recorded in the office files for future reference. There is no trace of the regular decrease in sucrose content from the early to the late canes in these tables, and the matter must be left undecided, until a more satisfactory series of experiments can be conducted. But, on considering the matter carefully, it occurs to us that it will be a matter of some difficulty to conduct such a series of experiments. As each clump approaches maturity, the average richness of its canes increases. This also occurs in each of its individual canes, but they do not run parallel in their improvement, in that the earlier ones will be ripe before the later ones. It appears, from a great number of analyses which we have made at various times, that, while the plants are young, there is a great difference in the richness of the juice in the canes of different orders of branching, but that this difference gradually diminishes as the usual harvesting time approaches; and, when it has passed, that the juice of the earlier formed canes commences to deteriorate until it is distinctly poorer than that

[1] A paper was presented at the Lahore Science Congress, Jan. 1918, in which this periodicity was dealt with. (The subject is further dealt with in a Memoir now in the press; February 1919.)

of later formed branches, which in their turn approach their optimum. This being the case, there will be a point of time in the life of each clump when the juice in the early and late canes tends to be of about the same richness, a period of equilibrium which may be regarded as the optimum of richness in the juice of the whole clump. It is probable that this point of time will vary in each clump of the same variety, even under the same conditions; it is likely that it will vary more in different varieties of the same group, and still more in the different groups. Besides this, the maximum richness of the juice in the clumps in any variety will naturally depend upon whether it is an early or late maturing kind. Mungo and Sunnabile varieties are later in maturing than Nargori and Saretha, and this opens up the question as to when the optimum as regards sucrose in the juice occurs, as it will of necessity be different in different varieties. Reaping all the canes at one time will therefore not be likely to give the desired information, for, while in some the *a*s are the richest, in others these will be overripe and the *b*s or *c*s will have taken their place. In the Pansahi group of canes there is evidence that, generally, the *a*s are richer than the *b*s, and so on throughout the series of canes in a clump, but we have not at present been able to adduce satisfactory evidence that this is the case at crop time in the other varieties dissected. We may therefore, for the present, regard the matter as left for further observation and experiment, and our increased knowledge of the characters by which early and late canes can be detected in a clump should assist in the carrying out of this study.

PART III. DISSECTION OF STOOLS.

(1) Scope of the work.

The number of cane plants dissected for the purpose of this paper is very large, as can be seen from the annexed table (pp. 99–100). It has been attempted to make them as representative as possible of the varieties collected on the Coimbatore farm. The growth of the indigenous canes there is, in general, fairly good, although some have shown themselves to be much more at home than others in the farm conditions, but the thick canes are often not well grown, and comparatively few of these were therefore chosen for dissection, and these rather for distinguishing them from the Indian canes than for comparison among themselves. As the canes of this class were thriving much better on the garden and wet lands of the Nellikuppam plantations in South Arcot, permission was obtained to send a man there for the completion of the series. I am much indebted to Mr. Neilson for his kind assistance in this matter, and the work seems to have been carefully done by Fieldman Rangaswami Pillai, who was in charge of it. We can thus add, to the series, the dissection of 24 clumps of well grown *Red Mauritius* canes, six each in wet and dry land, and a like number of ratooned clumps. All of the other dissected plants were grown on the Cane-breeding Station.

In ranging over so wide a field of study, as indicated by the list referred to and, so to speak, breaking new ground all the time, it was inevitable that many side issues should present themselves, of sufficient interest for further study. There were few mornings, devoted solidly to dissection, which passed without leaving on the mind some new idea as to the direction of the work. Most of these side issues have been prosecuted for a longer or shorter period, to give place in their turn to others, which obtruded themselves by the occurrence of startling examples of what had been casually noted before. The danger of this varying aspect of the work is obvious, both from the point of view of dissipation of energy and of obtaining a connected account, but the observations have, without doubt, afforded an insight into the growth of the cane which could not have been obtained otherwise.

As instances of these side issues, some of which were early incorporated in the work, while others were abandoned after a shorter or longer period of observation, may be mentioned the following. In not a few cases, hints were obtained as to subdivisions and cleavages in the groups of canes, by transitional forms, and these will be referred to later. In the young plants, the relative rates of cane formation in different varieties and groups, the varying length of the tillering period, the relative abundance of the buds of different orders, the large proportion of great white "clawed" buds in certain varieties which suggested a series of broods or flushes of branches, the relative rapidity of development of the main shoots compared with the side branches, and the form assumed by the young branches, often seen in the form of a fan at first, and quickly rearranging themselves to an orderly bunch.

In the older plants, the frequency of a symmetrical arrangement, in ground plan, of the branches when viewed from below, the arrangement and the orientation of the buds on successive branches, the suppression of buds on the inner side of the branches or where congestion occurred; the differing basal curvature of branches of different orders, the squeezing out of branches once formed, the way in which in some groups the branches rapidly became parallel while in others they curved outwards symmetrically or developed into an irregular mass, the manner in which the bud below a set curved upwards, and so on; the relative development of the middle and end buds of a set and the relative value of the position of a bud, whether underneath the set, at the side or on the top; the varying length of the basal, short-jointed portion of the cane in branches of different orders, the effect on this of curvature, with the general result that the mature form of the cane was not assumed until the curved portion was passed, the varying length of the joints in the first two feet; the different periods at which the final cane crop could be safely forecasted by the presence or absence of great shoots on the plant, the application of this to the order of dissection of the varieties; the changes in thickness and shape of the cane, the occasional presence of transverse or median flattening and the relative tereteness of the branches at two feet from the base in different varieties, the narrowing or thickening upwards after the average thickness had been attained, this varying both in different varieties and in the branches of different orders, the thickness and woodiness of the branches at their origin and the consequent firmness of attachment; the difficulties experienced in dissection and in the formation of diagrams and formulæ, due to the breaking off of branches, the intricacy of their development, the squeezing out of shoots, the numerous deaths, the occasional presence of facultative branches, where a branch of a higher order

assumed the characters of one of a lower order which had died, and particularly the difficulty of obtaining representative clumps and plants in certain varieties ; the relative incidence of different diseases, such as mealy bug in the young shoots, the deformations caused by moth-borer and white-ants and the extraordinary manner in which some varieties appeared to be immune to any infection of red rot ; the effect of all these factors on the varietal characters, and the frequent geographical grouping of subdivisions brought out by them.

It is thus not surprising that, during the course of the work, the general scope of the observations has from time to time undergone some modification, and it was not until the second year that a full scheme was developed for the study of each stool dissected. In some of the tables of measurements, only the dissections during 1917-18 are therefore considered. It was obvious that it was necessary to drop most of the side issues, after recording a note, as soon as a decision had been arrived at, and the following were the main lines followed in the second year, in which by far the larger number of dissections were made:—the evolution of a scheme of branching for each plant, variety or group and the discovery of a suitable formula and set of conventions for expressing this ; the relative thickness of each cane at two feet from its base, the length of the basal thickening, short-jointed portion, and the number and length of the joints in the first two feet after this basal portion had been passed ; the rate of maturing of the young plant as regards cane-formation ; the presence of curvatures at the base, runners, deaths, injuries and abnormalities of all kinds, etc. Details on these points are recorded in every dissection, and the various summaries and conclusions contained in this part of the Memoir have been derived from them.

List of clumps and plants dissected.

Group	Variety	1916-17	Young (usually 3-4 months) Clumps	Young (usually 3-4 months) Plants	Old (usually 8 months) Clumps	Old (usually 8 months) Plants	1917-18	Young (usually 3-5 months) Clumps	Young (usually 3-5 months) Plants	Old (usually 8-9 months) Clumps	Old (usually 8-9 months) Plants
Saretha	Ganda Cheni	...	1	2	2	4	..	2	4	2	5
	Chin	...	1	3	1	3	...	2	5	2	5
	Hullu Kabbu	...	1	2	1	2	...	2	6	2	6
	Katha	...	1	3	1	3	...	2	4	2	6
	Khari	...	1	3	1	3	...	4	13	2	5
	Saretha	...	1	3	1	2	...	2	7	4	14
Totals	for group	...	6	16	7	17	...	14	39	14	41
Nargori	Baroukha	...	...	...	...	...	...	2	5	2	4
	Katai	...	...	...	...	...	...	2	6	2	5
	Kewali	...	1	2	1	1	...	2	5	2	5
	Nargori	.	...	...	1	3	.	2	4	2	4
	Newra	...	..	...	...	...	...	2	6	2	5
	Sararoo	.	1	3	1	3	...	2	3	2	3
Totals	for group	..	2	5	3	7	.	12	29	12	26
Sunnabile	Bansa	...	1	2	1	1	..	2	6	2	5
	Bansi	...	1	2	1	3	...	...	..	...	...
	Dhaulu	...	...	..	...	..	...	2	2	2	10
	Dhor	.	1	3	1	4	...	6	13	2	4
	Kaghze	...	1	3	1	3	...	...	..	...	..
	Mojorah	...	...	...	...	...	.	2	2	2	6
	Naanal	...	1	3	1	3	..	2	7	2	5
	Sunnabile	.	1	3	1	2	...	2	6	2	6
Totals	for group	...	6	16	6	16	...	16	36	12	36
Mungo	Hemja	...	1	5	1	4	...	2	17	2	11
	Katara	.	...	...	...	...	.	2	3	4	12
	Kharwi	...	..	...	...	..		2	5	2	4
	Kuswar	...	1	3	1	3	...	2	6	2	7
	Mungo	...	...	...	1	3	...	2	7	2	8
	Rheora	...	...	...	...	...	...	2	11	2	13
Totals	for group		2	8	3	10	...	12	49	14	55
Pansahi	Chynia	...	...	...	...	...	...	2	6	2	2
	Kahu	...	...	...	...	...	...	2	5	2	5
	Maneria	...	1	3	1	1	...	2	5	2	6
	Pansahi	...	1	3	1	3	...	2	3	2	6
	Sada Khajee	...	...	...	...	...	..	2	4	2	3
	Yuba	...	...	...	...	...	.	2	5	2	4
Totals	for group	...	2	6	2	4	...	12	28	12	26
Unclassified Indigenous	Dhaulu of Phillaur	..	..	...	...	...	.	2	5	2	9
	Ikri	...	...	...	...	...	...	2	6	2	4
	Kassoer (Java)	..	...	...	...	...	...	2	5	2	3
	Khagri	.	...	...	...	...	...	2	5	2	6
	Khelia		1	3	1	2	.	2	6	2	4
	Teboe Monjet	...	...	...	...	...	...	2	5	2	5
Totals	per set	...	1	3	1	2	..	12	32	12	31

List of clumps and plants dissected—(concld.).

Group	Variety	1916-17	Young Clumps	Young Plants	Old Clumps	Old Plants	1917-18	Young Clumps	Young Plants	Old Clumps	Old Plants
Thick canes and intermediate indigenous	Java	8½-9½ months	...	...	3	7	...	(5 months) 2	3	(11 months) 2	5
	Louisiana Purple ..	...	...	...	...	...	...	...	...	(14 months) 2	3
	,, Striped ...	...	...	...	...	...	...	..	...	,, 4	10
	Magh	...	...	...	...	...	...	(5 months) 2	3	...	...
	Vendamukhi ...	...	...	...	...	...	...	,, 2	4	(9 months) 2	3
	Yerra	...	...	...	...	...	...	,, 2	6	(10½ months) 2	4
	Red Mauritius ...	...	(3½ months) 1	3	(9½ months) 1	2	...	,, 2	6	(10 months) 2	6
	,, ...	Ratoons	...	...	(20-25 months) 2	6	...	...	...	...	...
	,, Nellikuppam	Plant canes	...	...	...	...	Dry land	...	...	(12 months) 6	16
	,,	Plant canes	...	-	...	...	Wet land	...	...	(11½ months) 6	15
	,,	Ratoons	...	...	...	...	Dry land	...	...	(24 months) 6	10
	,,	,,	...	...	...	...	Wet land	...	...	,, 6	15
Totals	per group.		1	3	6	15	...	10	22	38	87
Wild Saccharums	Sacch. arundinaceum ..	...	...	...	(10 months) 1	2	...	(5 months) 2	5	(7½ months) 2	3
	Sacch. spont. local ...	...	...	...	(6 months) 2	3	...	(5 months) 2	4	(7½ months) 2	6
	,, Dacca ..	...	...	...	...	...	...	(4 months) 2	4	6-10½ months 6	13
	,, Java ...	...	...	...	...	...	...	,,	...	(7½ months) 2	7
	Saccharum Munja ...	...	...	...	...	...	...	(5 months) 2	5	(9 months) 2	5
	,, Narenga ...	..	...	..	...	...	...	,, 1	3	(9½ months) 1	1
Totals	per group.				3	5	...	9	21	15	35
Seedlings (planted from sets)	M. 5300 Str. Maur. Rogue	...	...	...	...	...	...	(4 months) 2	6	(8 months) 2	6
	M. 2 Kaludai Boothan Rogue	...	...	...	...	...	...	,, 2	3	...	...
	M. 7319 Ashy Maur. Rogue	...	...	...	...	...	...	,,	...	,, 2	4
	M. 1428 Naanal Rogue	...	...	...	...	...	...	,,	...	,, 2	4
	M. 2867 Vellai × Sacch. spont.	...	...	...	...	...	...	,, 2	4	,, 1	3
	M. 10801 Vellai × Sacch. spont.	...	...	...	...	...	...	,, 2	6	,, 2	5
Totals	per group							8	19	9	22

SUMMARY

		1916-17	Young Clumps	Young Plants	Old Clumps	Old Plants	1917-18	Young Clumps	Young Plants	Old Clumps	Old Plants
Saretha ...	Number of varieties 6	1916-17	6	16	7	17	1917-18	14	39	14	41
Nargori ...	,, ,, 6	...	2	5	3	7	...	12	29	12	26
Sunnabile ...	,, ,, 8	...	6	16	6	16	...	16	36	12	36
Mungo ...	,, ,, 6	...	2	8	3	10	...	12	49	14	55
Pansahi ...	,, ,, 6	...	2	6	2	4	...	12	28	12	26
Unclassified ...	,, ,, 6	...	1	3	1	2	...	12	32	12	31
Thick canes ...	,, ,, 7	...	1	3	6	15	...	10	22	38	87
Wild Saccharums	,, ,, 6	...	...	...	3	5	...	9	21	15	35
Madras seedlings	,, ,, 6	...	...	...	...	...	...	8	19	9	22
			20	57	31	76		105	275	138	359

Dissected : total clumps 294, total plants dissected 767

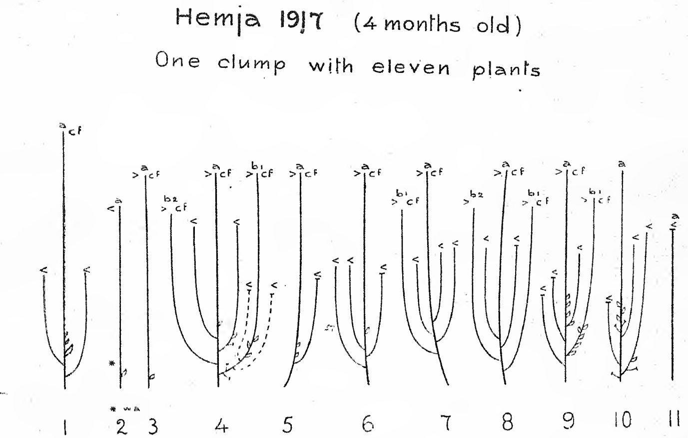
(2) THE GENERAL COURSE OF BRANCHING.

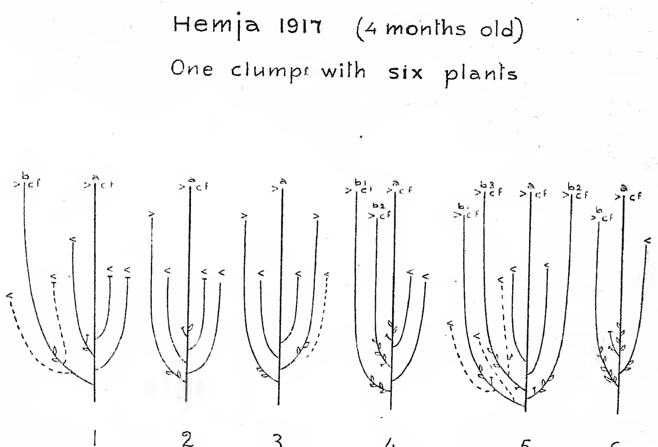
The sprouting of the buds of the set and their rapid transformation into cane shoots has been described in Part I of this paper (*cf.* pp. 46–50 and Plates IV–VIII). The bush resulting from the planting of a set is termed a *clump*. As there are several buds in each set (usually three in India), and each may give rise to an entirely independent set of stems, leaves and roots, we shall find it convenient to reserve the term *plant* for all that rises from the growth of a single bud. Similarly, we use the term *shoot* for any single axis which develops successive leaves at its apex and, in course of time, forms a cane. This distinction between clump and plant has been introduced in the preceding list of dissections, for it is obvious that the development of each plant will depend on the amount of space available, and this will be found expressed in the formula and diagram of its branching system, later on. Theoretically, with sufficient time and space, the development in any cane plant is practically unlimited, but we find, in practice, that there *are* certain limits in each variety beyond which the branching rarely goes, and that there are considerable differences in groups and varieties in this respect. The joints in the Mungo group are very short, and, in cutting the sets for planting, no care is taken to cut them so that they have only three buds, but a portion of the plant is cut off about the usual length. In our dissections in this group we have accordingly frequently met with a large number of plants in the clump. On Plate XVI the dissection diagrams of two young *Hemja* clumps are shown, with six and eleven plants respectively. Compare with these diagrams those on Plate XXX, in which an older clump of *Hemja* with four plants, and one of *Kuswar* with only one plant are shown. The numbers of living shoots in these clumps are as follows :— *Hemja* four plants 33, six plants 31, eleven plants 31, *Kuswar* one plant 24. The formulæ for such plants cannot reasonably be compared with those of other varieties where only three buds normally occur. It thus becomes a question whether, in preparing our diagrams and formulæ, the plant or clump should be considered the unit. There are, in every form, weak plants in which only a few canes are developed, and, taking a strongly branching form such as *Yuba*, we have the following formulæ for the four plants dissected: $1a+3b+1c$ and $1a+7b+16c+8d+1e$ from one clump, and $1a+3b+5c+2d$ and $1a+5b+5c+1d$ from the other (Pl. XXIII). Here we see a considerable difference between the development of the plants in the first clump, and there are far greater differences in other cases, where some of the plants consist of only one or two canes. On further considering the great number of individual plants in the clump in the varieties of the Mungo group, it thus becomes doubtful whether

the formulæ obtained for separate plants will be of any morphological value. Undoubtedly, if we planted a series of single budded sets, we should expect better data as to the tillering power of different varieties, but this would greatly limit the field of observation. We have, however, instituted such an experiment during the present season, with the added factor that each plant is allowed as much room as it is likely to be able to occupy. Meantime, it has been found that, with the large number of dissections made, the average formulæ obtained for different varieties are of service, and that the varieties examined differ sufficiently for their mode of branching to be added to the already numerous classification characters which we have observed in our study of indigenous Indian cane varieties. We have, indeed, an additional advantage in this variation in development of the individual plants, namely, that in each case we have a series of plants of different sizes, and are thus in a better position to judge of the ultimate possible development in each case. But, even if the limiting of our formulæ to the plant proved unsatisfactory, we could always at once deduce those for clumps by adding the respective plant formulæ together, whereas we could not make the converse adjustment. And, lastly, it is difficult to see how the *diagram* could be prepared with more than one original main shoot.

At the commencement of our work, it occurred to us that the position of the buds on the set might possibly have an influence on their growth. Thus the end buds of the set might, because of more room, develop into stronger plants, just as they do at the ends of the rows. But, as the result of many observations, we have not been able to trace any difference to this cause, as sometimes the middle bud was the largest and sometimes the end bud. The plants are apparently too close together for this factor to have any influence. Similarly, the relative positions of buds above or below the set had apparently no influence on the ultimate development of the plant, the arrangements whereby the shoots can alter their position being so perfect that they soon were able to place themselves in an equally favourable position (*cf.* Pl. VII, fig. 1, and also Note on p. 51).

We have seen that the bud on a set, on sprouting, develops more or less rapidly into a shoot consisting of joints, leaves, buds and roots. At an early stage of growth, the buds, especially the lower ones, push their way through the enveloping leaf sheaths and also form similar shoots. We indicate the main shoot by the letter *a*, and use *b*s for its branches, or those of the first order; the *b*s in turn give rise to *c*s or branches of the second order, and further branching proceeds on similar lines to the *d*s, *e*s, *f*s, etc., according to the variety



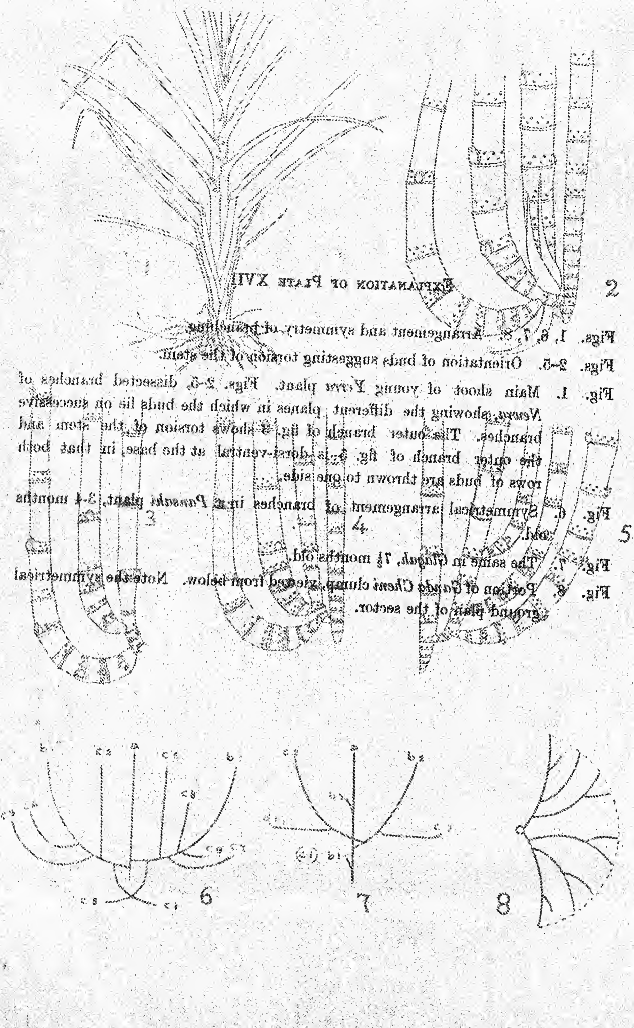


Diagrams of branching system in the plants of two *Hemja* clumps. These figures show what a number of small plants are sometimes found in each clump—which interferes with the comparative plant formula in the Mungo group.

or species and the amount of energy which each individual plant possesses. The *b*s develop more quickly than the *a*s, the *c*s more quickly than the *b*s and so on, until towards the end of the season when the energy available has been largely used up. This increasing rapidity in development is not to be wondered at, when we consider the larger mass of leaves and roots and the greater thickness of stems with their store of nutriment, as time passes and the plant becomes larger. This difference in the rate of growth in branches of successive orders leaves its impress on the final form assumed by the individual joints, especially the lower ones, and this makes it easy to deduce the previous rate of development from an examination of the dissections. At the point of origin, each shoot is extremely thin, and its first effort is to increase its thickness, until that appropriate to the variety has been reached. We have, empirically, but as the result of many observations, assumed that, until the joints reach about one inch in length, the shoot is still in this preparatory thickening stage, and also engaged in the process of branching, for most of the branches are found in this basal, short-jointed portion. And we thus obtain a useful indication of the rate of development of any shoot, by measuring the length of the portion before joints one inch long are reached. The *a*s or main shoots are all distinguished by a long basal portion. But we soon meet with another factor, which influences the length of this part of the stem. This is, that the later formed shoots have to place themselves between or outside the earlier ones before they can start growing freely, and they accordingly take a longer time in passing through their preparatory stage, the basal portion gradually becoming longer again in branches of higher orders.

In considering the way in which later shoots avoid congestion with the earlier ones, we have to study the whole question of the orientation of the buds on successive shoots, and the way in which the latter place themselves in a favourable position for free growth. The main shoot of the sugarcane plant, with its two rows of alternate leaves on opposite sides of the stem, assumes the form of a fan, as is seen in Pl. XVII, fig. 1. Each of these leaves bears a bud in its axil, and the branches, if developed strictly, should all be formed in the same plane. Each of these branches has a series of leaves, of which the first or lowest bud scale lies in the same plane, and, therefore, unless some disturbing influence supervenes the whole plant with all its complex of branches and leaves, if laid out on a table, would be flattened out in one plane. But this strictness of arrangement is usually avoided in nature, for the branches would interfere with one another and the distribution of light would be uneven. Thus, in *Pandanus*, where the leaves are arranged in a series of rows, there is an obvious but gradual torsion

of the stem, so that the vertical ranks of the leaves come to lie in all directions and they do not thus interfere with one another's light and air. There would appear to be a similar torsion, though not always very obvious, which finds expression in the varying *orientation of the buds* in the successive branches of the cane plant (Pl. XVII, figs. 2–5, see also the dissections on Pl. VI). This is specially seen where, as is often the case, the branching is congested low down, all the branches arising from a practically common centre. In other cases it can be noted that the lines of leaves at the base are not strictly opposed, but both tend to approximate to one or other side of the stem, usually the outer side. This dorsi-ventrality of the shoot is especially well seen in *Saccharum arundinaceum*, where the two rows of buds are both on the outer, curving side of the later branches, the inner side being altogether devoid of buds (*cf.* Pl. I, fig. 2 in the left-hand cane and fig. 5 of Pl. XVII). But yet another method is adopted by the plant, in that while the *a*s, and often the *b*s, are straight to the base, the later formed shoots are seen to curve in various directions, until a position is reached from which upward growth may proceed, unimpeded by the branches already formed (Pl. XVII, figs. 2–5). The character of this *curvature* varies a good deal in different varieties, and may attain considerable dimensions, and thus be regarded as a varietal character of some importance. Consider, for instance, the way in which the ultimate aim of the plant, to give all its shoots free access to light and air, is accomplished in the different groups. In the Saretha series the clump consists of straight or zigzag branches, sprawling in all directions and often almost lying down ; in Nargori, the canes assume a vertical position at the earliest possible moment and the curves at the base are comparatively short and sharp. In Pansahi, while the central shoots are erect, those outside curve very broadly and regularly, and the clump becomes cup-like in form, and so on (*see* Plates illustrating the groups at the end of this Part). And these various modes of growth, all leave their mark on the basal parts of the canes composing the clump. But this curvature is further assisted by the formation of *runners* which, again, are met with much more frequently in some varieties than in others. The term needs some explanation. We have applied it to those cases where, before the earlier thickening stage of the shoot is completed, one or more long thin joints are intercalated between the first short ones and the later ones, and the thickening process commences a second time. This gives the impression that the shoot, having started its growth along normal lines, finds itself cramped, but has still the power of changing its position, and does so by the formation of a runner. The plasticity of the fully formed branch is not sufficient for this to take place, and therefore runners are usually


2
3
4
5
6
7
8

Explanation of Plate XVII.

Figs. 1, 6, 7, 8. Arrangement and symmetry of branching.

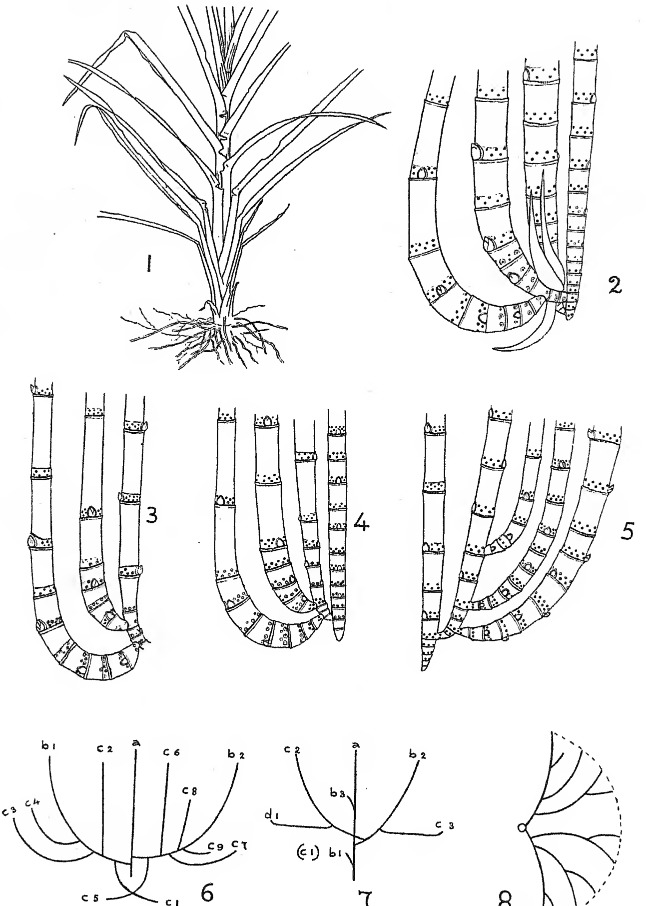
Figs. 2–5. Orientation of buds suggesting torsion of the stem.

Fig. 1. Main shoot of young *Yerra* plant. Figs. 2–5, dissected branches of *Newra*, showing the different planes in which the buds lie on successive branches. The outer branch of fig. 3 shows torsion of the stem and the outer branch of fig. 5 is dorsi-ventral at the base, in that both rows of buds are thrown to one side.

Fig. 6. Symmetrical arrangement of branches in a *Pansahi* plant, 3·4 months old.

Fig. 7. The same in *Glagah*, 7½ months old.

Fig. 8. Portion of *Ganda Cheni* clump, viewed from below. Note the symmetrical ground plan of the sector.


1
2
3
4
5
b1 c2 a c6 b2
c8
c3 c4
c9 c7
c5 c1
6
c2 a b2
b3
d1 c3
(c1) b1
7
8

confined to the basal, thickening portion of the shoot. It is not by any means necessary that runners should be formed only in a horizontal direction; they may trend downwards or upwards and, indeed, are not infrequently found in a vertical direction (*cf.* Pl. XXVIII). And in this case they remind one of the long preliminary joint formed in a seedling when it is too deeply planted and is not in a position to tiller freely. It is interesting to note that runners do not usually give rise to branches, and that, in the curved portions, it is usual for only the buds on the outer sides to form shoots, those on the inner sides remaining small or dying early.

The curvatures occurring at the base of the shoot are usually symmetrical through a number of joints, and both the nodes and internodes take part in it. In fully formed canes this is not possible in the internode because of the hardness of the rind, but at the node there remains throughout the life of the plant a meristematic zone which makes a bend possible. We thus come across *bends* in the canes long after the curving portion is passed, whereby a shoot is able to assume the erect position and regain it if accidentally thrown down, exactly as in grasses laid by a storm. This bending takes place chiefly in the "growth ring" which is usually greatly increased in width on the underside of the bend. In some varieties this nodal bending is characteristic of all the cane joints, whether it is necessary to alter the position of the cane or not and we accordingly get a *zigzag* cane with bendings in alternate directions. Zigzag joints usually occur in canes with long joints, and hence they are met with in the Saretha and Pansahi groups, but are absent in the short-jointed Sunnabile and Mungo varieties.

This arrangement of the branches of the cane is of great importance for its healthy development. Where the branches are too congested, the buds are suppressed and killed along the contact surfaces or, if they survive, they give rise to small, feeble, whiplike branches which are only very rarely able to force their way upwards and form canes. For the demonstration of this phase of the plant's activity, it is advisable to form a *ground plan* of the shoots, and this is sometimes very instructive. It is frequently possible to separate great sectors of the branching system by merely cutting through successive *b*s at their bases. Such separated portions often assume the form of a crescent and can be easily fitted into the other sectors, and an example of this is given in Plate XVII, fig. 8. Some of the schemes thus produced are highly symmetrical in vertical section (figs. 6 and 7), and show that the arrangement of the branches of the cane, with reference to the light available, is on a par with the fitting in of the leaves of a plant or the tops of the trees in the great primeval

forest. In the latter case, we have frequently been able to detect, on looking upwards, a hexagonal outline for the whole leafy top of an individual tree.

We can now return to the consideration of the way in which the rate and manner of development of the shoots, of different orders of branching, is impressed permanently on the morphological character of the mature canes.

We have measured the basal, short-jointed portion in each cane of each dissection, and find it longer, with a greater number of closely packed joints in the *a*s than in the *b*s and *c*s. In the later formed canes, however, we find the matter complicated by the incidence of curvature, and the length of this basal portion again tends to increase in the branches of higher orders, often indeed ultimately exceeding that in the main shoot. But there is no danger of confusing the different classes of branches on this account. Besides the actual curvature itself, which is absent in the *a*s, there is usually a great thickening in the curved portion in late branches, followed by a rapid thinning when the curved portion has passed; then the change in length is sudden, and quite long joints are immediately reached, as contrasted with the extremely leisurely increase in length in the earlier ones.

In measuring the length and thickness of branches of different orders we have confined our attention to the first two feet of cane. There are several reasons for this. In the first place the dissections would have been practically impossible, if a great mass of leafy canes was attached to the base during its manipulation, so it has been the custom, in the older canes, to cut the clump at three to four feet from the ground before bringing it to the laboratory. Then again, we have learnt, from our series of measurements of the length of joints, that, in the plotted curves, the joints reach their maximum very soon after the cane has emerged from the ground (*cf.* Chart II, p. 175, Mem. III). The longest joints are almost always met with in the first two or three feet, and afterwards there is a regular decrease until the end of the cane. Lastly, we have come to the conclusion that, at two feet from the ground, the thickness of the cane has reached a very fair average, although it is sometimes complicated by a varietal thickening or narrowing after this region has been passed.

In measuring the length of joints in the first two feet, we have omitted the unformed, basal portion, and only started measuring when the first inch-long joint has been encountered. This has also meant the omission of runners and, usually, the curved portion in later formed shoots. In other words, we have taken these measurements only in the fully formed cane. The results have shown a very marked increase in length of joint in the successive branchings, the joints in *b* being longer than those in *a*, and in *c* longer than *b*, and so forth.

In our former studies[1] we used this character to distinguish early and late canes, in that the early canes had short basal joints, while the later ones had longer ones, and we see that this method of distinguishing them was amply justified.

Besides the difference in length, there is also one in the thickness of the branches of different orders. The *b*s are usually thicker than the *a*s, and the *c*s than the *d*s, and so on throughout the series, until the amount of energy at the plant's disposal is exhausted. It may be postulated generally that this increase in length and thickness of joint is, in the main, connected with more rapid and energetic growth, and is the resultant of the action of the mass of roots and leaves present and available for the common use of the plant. Just as the leaves become successively broader and longer in the young plant, so do the stems increase in size. But when we apply this strictly to the successive orders of branches, we meet with another complication. A moment's thought will show that the *b*s in a plant are in a somewhat different position from the *c*s and *d*s. All the *b*s are borne on one shoot, the solitary *a*, but this is not the case in the *c*s and *d*s, which may be borne on any of several branches. We number the *b*s in their order of appearance on the stem, which roughly coincides with the time of their shooting. But in the *c*s we first number those on *b*1, then those on *b*2, and so on (*cf.* Pl. II). While then *b*1, *b*2, *b*3 are in more or less strict order of development, there is no means of telling the order in *c*1, *c*2, *c*3, etc., for it would be quite possible for the first *c* on *b*2 to arise before the second on *b*1. And this difference in the numbering of the *b*s and *c*s places the former in a better position for making observations on any increments in size according to the date of their origin during the plant's growth. For instance, by observing the measurements of successive *b*s, we learn that there is a tendency for an initial increase in size over the *a*s, soon reaching a maximum, and followed by a decline, when the amount of energy in the individual shoot is beginning to wane. There is in fact a general tendency for the *b*s to become thinner as we pass up *a*. A couple of examples, typical of a very large number of plants dissected, may suffice. In M.5300, II_2 of the list, the thickness of the four *b*s are, in mm., 170, 200, 165, 156; in *Kassoer* III the figures for the six *b*s are 274, 165, 167, 140, 121, respectively. This *tailing off* of the late *b*s accounts to a certain extent for the fact which will be noted later, that, in the general summation of the thickness of the branches of different orders, there is less difference between the averages in *a*s and *b*s than between those in the *b*s and *c*s. There are often thin *b*s at the end of the series, whereas

[1] Mem. III, p. 162, &c.

there are fewer *cs* on any one branch, and there is therefore less evidence of this tailing off. The *as*, if formed at all into strong shoots, are generally well grown, but of only moderate thickness.

The elementary facts here detailed, regarding the general course of growth of the cane plant, may with convenience be studied by a glance at the figures on Plate II of Memoir No. III, of a *Pansahi* plant, and the description of this Plate in the text. A more striking example is given in a couple of photographs of *Saccharum arundinaceum* on Plate I of the present Memoir, in which the variations in length and thickness of joints are very clearly shown. We may be excused for pointing out, in passing, a curious resemblance between the *Pansahi* canes and those of this wild Saccharum. Just as the irregularity and disorder of *Saccharum spontaneum* is seen in the general dissections of the Saretha group, the almost mathematical exactitude of *Saccharum arundinaceum* is reproduced in members of the *Pansahi* group, which, for a moment, suggests the possibility of genetic connection between the latter pair, as well as that now believed to exist between the two former; but this connection is not confirmed by a general study of the other characters which we have examined.

We have referred above to the early branching period of the growth of the cane plant, and we may now enquire if there is any indication of the same division into the two periods—tillering and elongating—which is seen in grasses (*cf.* pp. 52–55). The matter is complicated by the fact that there is not necessarily a flowering period in the sugarcane, when all the shoots are thrust simultaneously upwards, although the canes cannot attain their proper dimensions without being pushed up into the light and air. Furthermore, as soon as a cane shoot has attained its full thickness, it starts growing onwards in the upright direction exactly like a palm tree, and there is no halt in this upward growth until the inevitable slowing down towards harvest time. Thus, while one shoot is engaged in attaining its full thickness and giving off what branches are likely to have a chance of development, beneath the surface, another is already well formed, well above the ground and rapidly forming solid cane. We cannot therefore easily separate the growth of the plant, as a whole, into a tillering and elongation period, as in grasses. But this is less difficult where some external factor acts as a restrainer on the early growth of the plant. Such, as already noted, are the dry spell in the north of India during the early months of the year after planting, which tends to prolong the tillering period, and the drought in the Godavari District, caused by the annual cleaning out of the canals, often, as already mentioned, accompanied by a determined attack of shoot borer, which kills each shoot as soon as it emerges above ground. But, when we consider

each shoot separately, we see that there are two very distinct periods of growth in it, the first answering closely to the tillering period, when it is increasing in thickness and length of joint and is busy in forming its branches, and the second, when, after attaining its full thickness, it commences to form joints of appreciable length, and rapidly shoots into the air, a stage comparable with the elongating period in grasses. Thus the periods which characterize the shoots of the grass plant at one and the same time are present in the cane plant also, but in each shoot independently of the others. In spite of this fundamental difference, it is possible to separate cane varieties as to their general periods of growth. The term "cane formation" is well known in the fields, and is used to indicate the first appearance of solid canes between the bases of sheathing leaves just above the ground, and this cane formation differs a good deal in different varieties. It is, for instance, much more rapid in the Saretha than in the Sunnabile group (*see* Mem. III, p. 159 and Pl. IV), and still more so than in the later Mungo group. The length of the tillering period thus finds its expression in the rate of maturing of the canes in any clump, and this has been carefully studied in all the varieties; and a special series of dissections has been made for the purpose, at three to four months after planting.

(3) Diagrams and formulæ of the branching system.

In a previous paper a few pages were devoted to the branching system of the Saretha and Sunnabile groups of canes, and to these were added a diagram of the branching of a *Pansahi* plant with several photographs of dissected plants, showing the differences in length and thickness of joints in branches of successive orders (Mem. III, pp. 156–160). The conclusions arrived at were stated to be preliminary, as a much larger series of dissections was projected during the approaching season; but, from the work already done, it was suggested that, by studying the branching typical of any group of cane varieties, some idea might be obtained as to its relations with the more primitive forms on the one hand and the tropical canes on the other, and its place in the ascending series of evolution approximately gauged. Tentative formulæ were suggested to express the general course of branching in particular cases. This work has now considerably progressed, and the larger series of dissections has been completed, presenting us with a mass of interesting material for study.

The grouping of the cane varieties is that adopted in a short paper in the *Agricultural Journal of India* (Vol. XI, Part IV, Oct., 1916). Six varieties of each of the main groups, Saretha, Sunnabile, Pansahi, Nargori and Mungo,

were selected. To these were added six unclassified varieties of indigenous canes, including two recent importations from Java, four of the " Rogues " found in thick cane seedling plots, four wild Saccharum species growing in India, six thick cane varieties and a couple of crosses between these and *Saccharum spontaneum*. In each variety at least four clumps were dissected, two at 3–4 months from planting, in order to study early stages and to determine the rate of maturing, and two 7–10 months old, when the plants were more or less full grown, to obtain general formulæ of the canes and shoots at crop time. These varieties were grown in a special plot, in rows three feet apart and at distances of two feet in the row. The treatment was good and the soil fair. Most of the plants developed well, but in certain cases it was found difficult to obtain good representative specimens, and in such cases recourse was had to the ordinary variety plots, where there was a larger number of plants to choose from. The general aim was to secure moderately well grown plants, and all meagre, stunted clumps were rejected as unlikely to be of comparative value. There was, curiously, special difficulty in obtaining good specimens of both *Saccharum spontaneum* and thick tropical canes. Better specimens of the former were secured from the seedling plots, where *Saccharum spontaneum* was grown as a parent, and of the latter, as already stated, by sending a man down to Nellikuppam in the South Arcot District, where *Red Mauritius* was known to be growing luxuriantly under crop conditions. A certain number of ratoons were included among the thick canes, and, as in these cases the original piece of cane, planted two years before, was still attached, the results have proved of exceptional interest.

On a review of the formulæ obtained, and the general course of branching in the varieties and groups mentioned above, certain doubts have at times crept in as to the correctness of the classification adopted in the *Agricultural Journal* paper. In selecting the varieties for each group, it was attempted to obtain a general representative series, including specimens of all observed deviations from the typical varieties. Certain forms have shown themselves to be aberrant in their branching, and in other cases a series of transitions has been observed between the different types. Thus, in the Mungo group, *Kharwi*, a primitive form, differs a good deal from the rest, especially in the rate of maturing, and appears to approach *Dhaulu* in the Sunnabile group. The inclusion of this cane in the Mungo group will have to be reconsidered, especially as it was placed there as the result of only a cursory examination, owing to its recent arrival on the farm. *Katara*, also only tentatively placed in the Mungo group, and obviously somewhat deviating from the type, has shown in its dissections that it is transitional between *Kharwi* and the others.

The rest are in fairly close agreement with one another. It is interesting to note that, in the Saretha group, the division into the Katha and Mesangan sections receives support, in that *Katha*, *Saretha* and *Chin* develop much earlier than *Ganda Cheni*, *Khari*, and *Hullu Kabbu*. A similar cleavage now shows itself in the Sunnabile group, although this was only suspected when the varieties were examined in Memoir III. *Dhaulu*, *Bansa*, and *Mojorah* develop earlier and branch more copiously than *Dhor*, *Naanal* and *Sunnabile*. The position of *Mojorah*, the thickest in the group and nearest in several respects to thick canes, was unexpected, but it is worth while noting that, both in the Saretha and Sunnabile subdivisions, the cleavage indicated by the dissections is according to geographical regions, the earlier maturing, more richly branching forms being clustered along the Himalayas, while the tardier varieties are found in the Peninsula. In the *Nargori* group, which is generally marked by the homogeneity of its members, *Kewali* and *Ketari* differ somewhat from the rest. But in spite of these irregularities, the general result of the dissecting work has been abundantly to justify the general lines of classification adopted, and, as shown in the study of the Saretha and Sunnabile groups in Memoir III, the branching system yields a character of systematic value. It must be remembered that only a few varieties in each group have been studied, and these remarks on classification must therefore be regarded as suggestive rather than otherwise; but it is worth recording that subdivisions, such as are obvious in the Saretha group, may also be expected to occur in the other main classes, and it is hoped that the apparent uniformity of the various groups may break down on further study, for this is to be expected in any natural system of classification.

The form of the diagram, recording the dissections of plants in full grown clumps, is similar to that given for the *Pansahi* plant figured in Memoir III (p. 157), and the character of the lines used for the branches of different orders is the same as in that figure. Certain conventions have been introduced, which may be summarized as follows :—

(1) Sleeping buds are altogether omitted as having nothing to do with active branching. Only those much swollen or bursting have been included and their relative size is indicated. Large, white, clawed buds are, it is presumed, still under ground, and the dividing character between them and the small shoots is the presence or absence of any green at the tips.

(2) Dead buds are indicated by a short line with a cross line at the end. The same cross line shows dead shoots or canes. Most of the diagrams have no distinction between resting and burst buds, which have died.

(3) The term " shoots " is reserved for such as have green leaves, and these vary from tiny ones just emerged above the ground to those already forming immature canes. They do not reach the top of the diagram, this position being reserved for what are considered fully grown canes; the length of the shoots is indicated by a set of empirical figures, $1'$, $2'$, $3'$, etc., which roughly indicate the relative stage of development without accurate measurements having been taken. When shoots are large and have formed canes below, which, it is assumed, would be sufficiently matured to reap as canes at harvest, they are distinguished by the letters *cf*, *i.e.*, cane-forming, at their ends, and such shoots are included in the formula of canes at harvest.

(4) The term " runners " is used in rather a wide sense, as described on page 104. When the initial thickening stage at the base of the young shoot is interrupted, and a few thin, long joints are intercalated, after which the thickening is resumed, this intercalated portion is called a runner. They are specially found in late formed canes, where the space available is not sufficient for free growth; but it is to be noted that they occur more frequently in some varieties and groups than in others. They are marked in the diagram by an added fine parallel line along the part where they occur. Examples may be seen in Plates XVIII and XXX

(5) Attacks of white-ants and moth-borer, and other injuries, are indicated by an asterisk with descriptive letters added. Shoots thus attacked are usually rejected in forming averages, because of the disturbances induced in the length and thickness of the joints following the injury.

A couple of diagrams are appended in which these conventions are used. We have selected *Katha* I3 and *Sunnabile* I3 of the list, as showing most of them clearly (Plate XVIII).

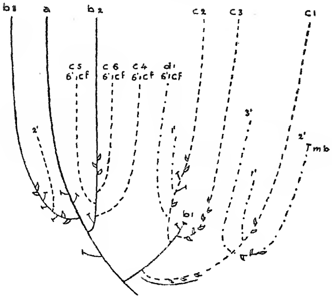
The formulæ of these are as follows :—

Katha I3. Canes, $a+4b+4c+5d$; shoots, $3c+2d$; buds, $3c+5d$; Dead, $1b+7c+4d$; Runner, $1d$.

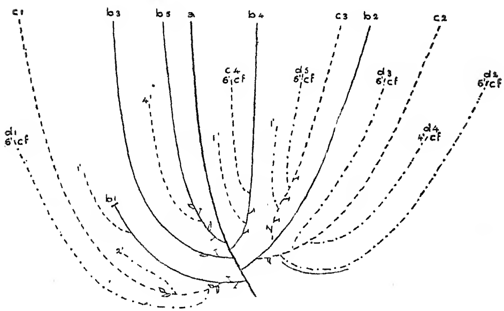
Sunnabile I3. Canes, $a+2b+6c+d$; shoots, $1c+3d$; buds, $7c+14d+3e$; Dead, $4b+5c+2d$; Runner, $1c$.

A word is here necessary as to the time at which the dissections were made. It was unfortunately impossible to dissect the different varieties at the same time. It is rather a tedious process, and the number done was very large. In the 3–4 months' dissections, the time occupied was about six weeks, and it was arranged to do the early maturing kinds first, and leave such late groups as the Mungo until the end. This was found to give satisfaction, although of course the observed differences in the rate of maturing were thus

Sunnabile I 3



Katha I 3



Two diagrams of the branching in dissected plants, to illustrate the conventions used.

made less than the reality (*cf.* p. 127). The 8–10 months' clumps took at least three months to dissect, but the same method was adopted, and it was found that it was perfectly possible, at this stage, to decide what canes would be matured at harvest time. This, however, applied only to the cultivated canes. The wild Saccharums do not exhibit any special ripening, as for a crop time, and the dissections made from six to nine months show great individual variations in the rate of cane-formation. There was, in these forms generally, an absence of large shoots which were not cane-forming at the base, at whatever time the dissection took place, and in this respect they were at variance with the rest. This fact shows that, in the cultivated canes, the general plan of cane-formation for the season is laid down months before the harvest, and the differences in the periods at which the dissections were made were of little importance with regard to the end in view, which was to obtain a scheme for each plant of the number and character of the canes formed, with a general view of the shoots and buds and deaths occurring. The thick canes were dissected late, on the assumption that cane-formation was very tardy; but this has not turned out to be altogether the case, as will be seen later. The matter is, however, of less importance, in that most of the thick canes were dissected at crop time, and thus all immature canes were at once rejected as not fit for cutting at harvest.

The work was not without its special difficulties. The absence of well grown representative specimens in some varieties in the dissection plots has already been referred to. It is probable that, in these forms, not usually growing well at the Cane-breeding Station, a more elaborate form of branching may be more characteristic, as, for instance, in members of the Katha section of the Saretha group, but this irregularity in the development of varieties would probably occur at any one place where all the forms were being grown together; and in the present case it was merely considered sufficient to note in the record that such and such variety was poorly grown. In some cases the branches were formed very near the base of the stem, and so intricate a mass was revealed that it was almost impossible to get a connected picture of the branching system. This was, for instance, the case with *Kaghze*, which, however, for other reasons, was rejected in the later dissections. In yet other cases, the attachment of the canes at their base, whether to the original set or to the later stems, was extremely thin and brittle. Such were bodily removed, their places of insertion being marked by a series of duplicated pins with numbers attached, and the general plant was then reconstructed after all the sectors had been independently dissected. But a study of this firmness of attachment showed at once that it varied greatly in the different groups,

the *Chin* allies being very lightly fixed together, while in the Pansahi group there were thick, broad attachments which gave the impression of growth in thickness for some time after their formation. While then, it was very difficult to do the Saretha dissections, it was always easy to lay out great sectors of the Pansahi clumps with all the branches attached. The firmness of the attachment is of some importance as a group character and notes have been recorded on it.

Another more puzzling factor was the frequent deaths of both young and old branches. There seemed to be some ground for assuming that, when a stem died, its place would be taken by one of its branches, which would take on its characters in whole or in part and thus become a *facultative branch* of a lower order. In other words, when an *a* died, its place might be taken by one or more *b*s, which would assume *a* characters. This would, of course, interfere fundamentally with the typical diagram, as well as the distinction of the classes *a* and *b* in that plant. We have seen that there are a number of characters by which we can distinguish between the branches of successive orders, and we have always kept an eye open for the presence of facultative branches. And there have been, undoubtedly, a number of cases where these occurred; but in the great majority of the specimens examined, the death of an *a* did not seem to have a very great influence on the measurements of *b*s and subsequent branches formed. There were, however, all stages between a very slight or doubtful influence and an obvious facultative *b*, so that, wherever possible, plants with sound *a*s were used for dissection. Some varieties appear to be much more liable to lose their *a*s than others; for instance, in Saretha, it was found impossible to do without a considerable number of missing *a*s in spite of a large number of clumps dissected. It is probable that the time at which death occurs has a considerable influence in the matter. If it occurred when the successors had already formed their basal joints, its influence would be small, as our observations have been confined to the lower parts of the cane. If, on the other hand, the death of a shoot occurred very early, it would be quite possible for a facultative branch to take its place for the purpose of producing the necessary number of shoots in the plant. Although the formation of such a facultative branch is by no means a necessary sequel to the early death of a shoot, it somewhat seriously interferes with the regularity of the diagram. For instance, if a *c* dies after its basal portion is formed, it gives rise to one or more *d*s, and thus lengthens the formula. A case of this can be seen in the diagrams illustrating the branching of Thick canes (Pl. XXXII, lower figure). There are two plants in the clump and their formulæ are, for the smaller plant, $a+4b+1c+2d+e$, and, for the larger, $a+4b+6c+d$.

An examination of the figures shows that a c has died early in the smaller plant and that from its stump $2ds$ and $1e$ arise. If this death had not occurred, the formula would have been $a+4b+2c$ or perhaps $a+4b+2c+d$, and the unusual e would certainly not have been developed. And many similar examples could be given, where the death of an a, b or c, causes an abnormal lengthening of formula.

Lastly, the congestion at the base in such forms as *Chin* and *Kaghze* introduces numerous irregularities which interfere with the formulæ and the measurements taken, it apparently being the merest chance whether suppression occurs or meagre shoots survive for a time, or a cane forces its way through and ultimately matures, often showing marks of its struggle for existence. All of these and other factors have their influence on the regularity and symmetry of the branching system, and have made the preparation of characteristic formulæ more difficult.

Appended is a summary list of the formulæ of canes at crop time for each group of varieties dissected. In this list, fractions are treated in the usual way, in that halves and fractions below a half are ignored, while fractions over one-half are counted as equal to one. In some cases there is only one variety in the formula, as in *Saccharum arundinaceum* and the *Red Mauritius* cane, dissected at Nellikuppam. The six unclassified indigenous Indian varieties do not of course form a group, but have been taken together in this list. In *Saccharum spontaneum* there are three varieties, which differ among themselves even more than the ordinary varieties of a group, but they have been taken together for convenience. There are six varieties each in the Saretha, Pansahi, Nargori, Mungo, Sunnabile and Thick cane groups. To these are added four Rogues from thick cane plots and two Crosses between a thick cane and *Saccharum spontaneum*. The group formulæ are prepared in two different ways. At first the formula was obtained for each variety, and these formulæ were averaged for the group to which they belonged. But it was thought possible that a better average would be obtained if all the plants in each group were added together and averaged, and this was accordingly done The two sets of figures are distinguished by the words " varieties " and "plants" in column No. 2. Besides these formulæ of canes at crop time, a summary has been made of all the stems and branches, with their shoots and buds whether living or dead. These will, it is thought, give a general idea of the branching capacity of the whole plant, but these combined formulæ are less symmetrical and instructive than those of canes at crop time. The latter may be regarded, in some sort, as the total output of the plant, analogous to the

ear heads of a cereal, for the cane plant has long been cultivated for the special development of as many matured canes as possible.

Average plant formulæ of the groups dissected.

Group	Averages of plants or varieties	Number	Canes at crop							Canes, shoots, buds and deaths							
			a	b	c	d	e	f	Total	a	b	c	d	e	f	g	Total
Saccharum arundinaceum	Plants ...	5	1	4	6	6	5	0·4	22	1	4	10	9	9	7	2	42
Saccharum spontaneum	Plants ..	17	1	4	7	5	2	0·4	19	1	5	16	25	11	3	1	62
	Varieties .	3	1	4	6	5	2	0·4	18	1	5	15	24	11	3	1	60
Pansahi ...	Plants ...	29	1	3	4	2	.	..	10	1	6	13	14	6		...	40
	Varieties ...	6	1	3	4	3	...	...	11	1	6	14	17	7	...		45
Mungo ...	Plants ..	59	1	2	2	1	..	...	6	1	7	17	11	3	...	.	39
	Varieties ...	6	1	3	3	2	...	...	9	1	7	18	14	5	..	...	45
Saretha ...	Plants ...	53	1	3	3	1	...	...	8	1	6	14	10	2	...	...	33
	Varieties ...	6	1	3	3	1	..	...	8	1	6	15	10	2	...		34
Nargori ...	Plants ...	33	1	3	3	...	...	...	7	1	5	12	4	...	...	.	22
	Varieties ...	6	1	3	3	...	...	...	7	1	5	12	4	.	...	...	22
Sunnabile ..	Plants ...	46	1	3	2	...	...	...	6	1	7	17	7	..	...	...	32
	Varieties ..	6	1	3	2	...	..	...	6	1	8	16	6	...	...	...	31
Thick canes { Cane-breeding Station }	Plants ...	41	1	2	1	...	...	...	4	1	7	11	7	...	..	...	26
	Varieties ...	6	1	2	1	...	...	..	4	1	8	12	8	...	.	..	29
Red Mauritius { Nellikuppam }	Plants ...	12	1	3	3	1	...	...	8	1	9	19	8	1	...	.	38
Unclassified indigenous varieties	Varieties (6)	plants 33	1	4	2	..	...	..	7	1	9	24	9	...	...	...	43
Rogues in thick cane plots	Varieties (4)	plants 17	1	3	5	4	0·5	...	13	1	8	19	24	9	1	...	62
Crosses, Thick canes by wild Saccharums	Varieties (2)	plants 8	1	3	3	...	...	...	7	1	6	22	15	...	...	...	44

With regard to these two methods of obtaining the formulæ, it may be noted that, for canes formed at harvest, the two methods show little difference in the result. The greatest difference is seen in the Mungo group, where the summation of the 59 separate plants gives a formulæ of $1a+2b+2c+1d$, whereas that taken by averaging the six varietal formula is $1a+3b+3c+2d$.

The two formulæ for Saretha, Nargori, Sunnabile and the Thick cane group are identical, and in the rest only differ in one figure. In the table the groups have been arranged according to the length of the formulæ. The wild Saccharums and the Thick canes are, as might be expected, at the ends of the series, and the indigenous Indian groups occupy an intermediate position. The *Red Mauritius* canes grown at Nellikuppam show an extension of the formula over that of the six varieties grown at the Cane-breeding Station. One idea in having these canes dissected was to see how far the formula of a thick cane might be extended under favourable conditions. Only good clumps were dissected, the distance between the rows was four to five feet in place of three feet at Coimbatore, and there could not well have been greater difference in the character of the soil. That at Nellikuppam is a free sandy loam not unlike the soils met with in the Gangetic alluvium, in place of the rather heavy, slightly saltish land at Coimbatore. Besides this, the *Red Mauritius* variety is noted as a rather free tillering kind. We have accordingly kept this series separate, for, if comparisons are to be instituted between them and the Indian canes, these too should be grown in the places best suited to them. There were many plants in the clumps of most of the varieties dissected which were poorly grown, often only consisting of one or two canes, and there were also, occasionally, abnormally large single plants. By the employment of a sufficiently large number of individual dissections, both of these extremes have been ruled out, and it is assumed that a fair average has been obtained for each variety and group.

The wild Saccharums head the list in the extension of their formulæ, and the large number of *es* in *Saccharum arundinaceum* suggest that a single *f* might with propriety be added to complete the series, which would then be 1 : 4 : 6 : 6 : 5 : 1. The average figures have accordingly been examined to see what decimals were present at the end of each formula. Where such a decimal exceeds one-quarter, it has been inserted, and it is seen that this only occurs in the wild Saccharums and the Rogues from the thick cane plots. We should expect that the full form of the Pansahi formula would be 1 : 3 : 4 : 3 : 1, Nargori 1 : 3 : 3 : 1, and perhaps Sunnabile 1 : 3 : 2 : 1, but the decimals which could be added are insignificant. We may therefore suggest that well grown specimens, or those under suitable conditions of growth, are likely to have such an extension of the formula, as there is a marked tendency in all the formulæ for a fairly symmetrical series of figures.

As regards the acclimatization of the different kinds, *Saccharum arundinaceum* appears to be either very hardy or perfectly at home. The latter is

most probable, as this plant has been grown for many generations in the south of India, and indeed in the immediate neighbourhood of the farm, on richly cultivated land as a fence round *betel* (*Piper Betle*) gardens. The Pansahi group seems to be also very hardy and little incommoded by the occasional saltness of the land on the farm. Saretha varieties of the Katha section do not grow well on the farm, and *Saccharum spontaneum* is not, at first, at home in the cultivated land. The Mungo series is obviously at a disadvantage because of the comparatively large number of plants per clump. The result given in the table must therefore be taken as for one place only, with its many peculiarities, in many cases not the best suited for free growth of the variety. But it is improbable that any one place could be found where all the varieties grown would be equally at home. With this word of warning, we can proceed to analyse the averages in the table. The Thick canes, in the character of their branching, show themselves furthest removed from the wild Saccharums. Then come in order the Sunnabile and Nargori groups which approach the Thick canes, then Saretha, Mungo and Pansahi, which are nearer to the wild kinds. There is no reason to assume, only from the formulæ above given, that Saretha is nearest to *Saccharum spontaneum*, although we have noted many other similarities in Memoir III. The suggestion rather obtrudes itself afresh that the Mungo and Pansahi groups of canes may have arisen independently from some wild parent, and this agrees with the strongly marked characters of these types. The details in each group find no place here, and would fill up a large number of pages. A few notes on them are added at the end of the Memoir.

The above remarks refer to the formulæ obtained from averaging the canes formed at crop time. Shoots and burst buds and dead branches also have their significance in the branching system, and we have included these in a second series of columns. We may now turn to them to see if they show anything of interest. It must be acknowledged, however, that the deaths have not been very wisely marked down in the dissections. For them to be strictly included in the branching system, only dead buds which had already burst should have been counted. But while this was done at first, towards the end of the work all dead buds were counted, on the assumption that they died in the effort of growing out, which was probably often not the case. On considering the enlarged formulæ, we find that the general tendency is the same as that in the canes at crop time. The Sunnabile and Nargori groups are now indistinguishable from the Thick canes, the greater shooting in the latter being possibly due to their encouragement in the process of ratooning or growing for a second year from the same root stock. Some note may be taken of the

different degrees of development of certain classes of buds and shoots in the different classes. In *Saccharum spontaneum* and the Rogues from the thick cane plots, it is the *d*s which form the bulk, these groups being closely followed in this by the luxuriantly growing members of the Pansahi group. But in the latter, the *c*s are nearly as well developed, and this order of shoots is dominant in the other groups, especially in the Nargori and Sunnabile forms. This dominance of certain orders of branches is probably connected with the formulæ already discussed above, the tendency being in each case for the full series of branches not to be symmetrical, but for the maximum to be thrown forward, so that the higher members come beyond the middle of the series.

Turning to the formulæ in the odd lots, the six unclassified indigenous canes, the Rogues and the Crosses between a thick cane and *Saccharum spontaneum* show certain peculiarities. The cane formula for the six unclassified indigenous varieties is very short. This can be easily accounted for by an examination of the varieties selected. They were not intended to be representative in any way, but were such as for one reason or another were interesting. Thus the three *Khelia*, *Khagri* and *Ikri*, apparently closely related to one another, showed a considerable likeness to the Thick canes, and *Teboe Monjet* has a similar formula. *Dhaulu of Phillaur* approaches Sunnabile in its formula. This was rather unexpected, as this form is considered, from other characters, to be near the Mungo group, but its formula suggests the idea that it may be a connecting link between the Mungo and Sunnabile groups. *Kassoer*, a strong-growing Java form, has the only extended formula, and resembles Saretha in this. The average of the six cannot therefore be taken as representative of indigenous Indian canes generally, and they were not intended to be so.

The Rogues show a very long formula and produce an immense number of shoots of all kinds. This is in accordance with their great vigour and marked primitive characters. The crosses of *Vellai* by *Saccharum spontaneum*, on the other hand, show surprisingly little influence of the male parent in their branching. The formula is extremely short, practically that of Nargori and Sunnabile, which groups are near to the Thick canes. This nearness to the Thick canes is also shown in the richness of the juice in these two seedlings, which is not in any way intermediate between the wild Saccharums and *Vellai*.

(4) AVERAGE LENGTH OF THE BASAL, THICKENING PORTION OF THE CANE, IN BRANCHES OF DIFFERENT ORDERS.

It was noted above that, in judging the average length of the joints in the lowest two feet of cane, the narrow basal region, where the

6

joints had not as yet reached one inch in length and were still in the process of thickening, was excluded. The selection of this one inch length is purely empirical, but it answers the purpose well enough. The joints in this region are very numerous and, towards the base, present the appearance of a series of superposed discs, with difficulty separated from one another. We may consider this portion of the cane as that engaged in attaining its full thickness and in giving off branches, as contrasted with the following elongating portion, and it presents certain characters which may be now briefly considered. As it is the formative region, in which the whole system of branches must arise, it is not surprising that it is longer in the main stem than in its branches. It has been measured in all the canes in each plant examined, and the table shows the general averages of each group. We see there, that, while in the *a*s of all the groups its average length is 3·7″, it is 2·6″ in the *b*s. We should expect a similar difference between the *b*s and the *c*s and so on, but this is not the case. In fact, in most groups, there is a distinct increase in the length of the basal part in succeeding branches after the *b*s are passed. This fact has been already explained by the presence in these later branches of curvatures, whereby they may be placed in a better position for developing freely. And it has been noted that, where there is such a curve, the joints remain short until the cane has straightened out and is in a position to grow upwards in a vertical line. In the Thick canes, in the Mungo group and in *Saccharum spontaneum*, there is a continuous reduction in the length of the basal part throughout the series of branches. This is readily explained in the first and last cases, in that curvature is generally less evident in them, in the Thick canes because of their comparative fewness, and in the wild Saccharum because of the thinness of its branches, their general irregularity and the constant presence of runners. In *Saccharum spontaneum* the shoots are placed in a position for free development rather by runners than by curves, and the result is that the whole complex of branches in the clump is loosely knit together instead of being closely compacted as in the cultivated canes. In Mungo the case is different. There are a great number of canes in the clump, but these arise from a large number of separate buds, as many as 11 having been noted in one case. It is possible that this even distribution of the individual plants along the length of the set may serve the purpose of placing them, and thus do away with the necessity of much curving. But curving is present, as also are runners, and the regular decrease in the lengths of the basal portions of branches of successive orders comes somewhat as a surprise. We have to wait until the *d*s, before we get the expected increase in length. With these two tendencies in opposite directions, we get, in the averages of all the groups, a uniformity in the lengths in

bs, *cs*, and *ds*, which is rarely met with in the individual plants. As in other cases, we have to turn to *Saccharum arundinaceum* for the complete regularity of the series. Here the lengths in *a* average 2·9″, and there is a sharp drop to the *bs* with 2·1″, followed by increases to 2·4″, 2·9″, 3·2″, in the succeeding branches of higher orders. A glance at the uprooted clump in this species will show the increasing curvature which is a dominant factor in this character (*cf.* Pl. I).

Average length of basal part, with joints under 1″ in length, in inches.

Group	No. of varieties	*a*	*b*	*c*	*d*	*e*	*f*	Remarks
Saretha	6	3·1	2·0	2·1	2·5	2·3	(1·5)	The figures in brackets are such as occur only in one case and may be disregarded as not representing an average for the group.
Sunnabile	6	2·7	2·1	3·2	2·6	...	...	
Pansahi	6	3·4	1·7	2·0	2·4	(2·0)	...	
Nargori	6	5·6	2·5	2·8	(2·1)	...	...	
Mungo	6	4·6	3·6	2·7	3·7	(2·3)	...	
Various indigenous ...	6	5·0	3·3	3·1	3·4			
Rogues	4	3·9	2·6	2·9	2·5	(2·1)	(1·5)	
Crosses	2	2·8	2·4	2·8	(3·8)	..	...	
Thick canes	6	4·3	3·7	3·3	(3·4)	...	...	
Red Mauritius at Nellikuppam	1	3·5	2·8	2·5	2·3	1·9	...	
Saccharum spontaneum ...	3	2·6	2·0	1·6	1·6	1·9	(0·6)	
Saccharum arundinaceum ...	1	2·9	2·1	2·4	2·9	3·2	...	
Average of all the groups ...	...	3·7	2·6	2·6	2·7	2·4	...	

(5) Average length of joints in branches of different orders.

The main shoot arising from a bud on a set is different from its branches in several respects. It has been shown that it takes longer to develop, in that the plant is small and weak at first; it has a longer basal, branching portion; it is also markedly shorter jointed than its successors. This will be seen from the Table, where the lengths of joints in the *as*, *bs*, *cs* and branches of higher orders have been averaged for the different groups. It may be noted that the numbers of branches dealt with are not the same as in the formulæ of matured canes, for even immature canes have been included, if it was possible to measure the lengths of the joints in the first 20″. It is well known that the lengthening of these joints, once they are formed, is extremely small and may be neglected.[1]

The averages have been obtained in three ways, the *as*, *bs*, etc., of each plant have been averaged separately, the averages for the varieties have been obtained from these, and these latter have been again averaged for the groups

[1] Kuijper, J. De groei van bladschijf, bladscheede en stengel van het suikerriet. *Med. Java Suikerind.*, V., 8, 1915.

(column 1). Secondly, all the *as*, *bs*, etc., of each variety have been averaged, and these variety averages have given those of the group (column 2). Thirdly, all the *as*, *bs*, etc., of each group have been taken together (column 3). It is remarkable how little difference there is in the three resulting sets of figures. There is a steady rise in the average length of joints in every single group, and sometimes a sudden increase between the *bs* and *cs*. The reason for the selection of the two lowest feet of the cane for these measurements has been already given in detail (p. 106).

In the Table, where there are less than four measurements of a branch of one order in a group, the resulting average is placed in brackets, as insufficiently reliable for the group average. Such figures are however included in the total summation at the foot of the Table. If less than 20″ can be measured, the cane is rejected as immature. The joints of runners are omitted and the lengths of joints are not measured until the short-jointed portion following the runner is passed. If moth-borer or other injury is noted as reducing the length of the joints above it, the cane is rejected; this is judged by comparison with other branches of the same order in the same plant.

Average length of joints (above basal part) in the first 2′, in inches.

Groups	No. of varieties	Number of branches of different orders						All the branches of the same order taken together: In each plant						In each variety						In each group					
		a	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*
Saretha	6	29	109	77	20	(2)	...	2·1	2·8	3·3	3·5	(3·0)	...	2·1	2·8	3·3	3·6	(3·0)	...	2·2	2·9	3·4	3·6	(3·0)	...
Sunnabile	6	35	101	60	(2)	...	...	1·9	2·3	2·7	(2·5)	...	...	1·9	2·3	2·9	(2·5)	...	...	1·9	2·4	3·0	(2·5)	...	...
Pansahi	6	20	69	75	32	...	...	2·2	2·9	3·6	4·4	...	...	2·2	2·8	3·6	4·5	...	...	2·2	2·8	3·6	4·5	...	...
Nargori	6	19	71	72	(1)	...	...	2·0	2·5	3·6	(3·5)	...	...	2·0	2·6	3·7	(3·5)	...	...	2·1	2·6	3·8	(3·5)	...	...
Mungo	6	38	139	102	28	(1)	...	1·7	2·0	2·1	2·5	(1·8)	...	1·7	2·0	2·1	2·5	(1·8)	...	1·7	2·0	2·2	2·8	(1·8)	...
Unclassified indigenous ...	6	31	94	48	4	...	...	2·2	2·9	3·2	3·8	...	...	2·2	2·9	3·2	3·8	...	...	2·1	2·9	3·3	4·1	...	...
Rogues	4	14	61	87	49	6	(1)	2·5	3·4	3·8	3·8	3·9	(3·9)	2·5	3·4	3·7	3·8	3·9	(3·9)	2·6	3·4	3·7	3·8	4·0	(3·9)
Crosses	2	8	29	25	(1)	...	...	2·7	3·1	3·4	(3·8)	...	...	2·7	3·1	3·2	(3·8)	...	...	2·7	3·1	3·4	(3·8)	...	...
Thick canes ...	6	24	51	42	6	...	...	1·8	2·3	2·8	3·0	...	...	1·8	2·4	2·8	3·0	...	...	1·9	2·4	2·7	2·7	...	...
Red Mauritius at Nellikuppam	1	30	89	74	23	(3)	...	2·6	3·1	3·3	3·3	(4·5)	...	2·6	3·1	3·2	3·3	(4·2)	...	2·6	3·1	3·4	3·4	(4·2)	...
Saccharum spontaneum	3	17	63	86	34	7	(2)	2·7	3·5	3·9	4·0	4·4	(4·8)	2·7	3·5	3·8	4·0	4·4	(4·8)	2·7	3·4	3·6	4·1	4·5	(4·8)
Saccharum arundinaceum	1	3	16	26	22	18	...	2·1	3·3	5·2	5·8	6·5	...	2·1	3·2	5·0	5·7	6·4	...	2·1	3·2	5·0	5·7	6·4	...
Average of all the groups	...	...	...	...	...	...	...	2·2	2·8	3·4	3·7	4·0	4·3	2·2	2·8	3·4	3·8	3·9	4·3	2·2	2·8	3·4	3·7	4·0	4·3

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(6) Average thickness of branches of different orders.

As we pass from the main shoots to branches of higher orders, we note, in the dissections, a steady increase in the thickness of the canes. This is not to be wondered at, if we regard each shoot as being furnished with a certain amount of energy of growth. Much of this energy is used up in the main shoot in its change from the infinitesimal stem of the young seedling to a cane of definite thickness. The branches, on the other hand, not only are thicker at the start, but pass through their forming process much more rapidly, and it is to be expected that, before their energy wanes, stronger, thicker canes will be produced.

To compare the thickness of the canes, all have been measured in each plant at about 2′ from the base, where it is reasonable to suppose that the cane has completed its growth in thickness. The measurements were made by calipers in the lateral plane, thus ruling out the ovalness of some varieties, the longer diameter usually occurring in the median plane or that in which the buds lie. The markings on the calipers are in mm., and the results are accordingly given in the metric system. The following are the average thicknesses, in mm., of the main stem and its branches of different degree, in all the groups dissected, *a* 177, *b* 187, *c* 207, *d* 228, *e* 219, *f* 88. The last two figures are not true averages, *f* only occurring in the thinnest form, namely, *Saccharum spontaneum*, and *e* being absent in the Thick canes, Sunnabile, Nargori, Unclassified indigenous and Crosses, in all of which groups the branches which are present show markedly rapid increases. As in the case of the average length of joints, there is a distinct advance from *a* to *b*, but there is a much greater one from *b* to *c*. In the main groups of indigenous Indian canes, there is less difference between the *as* and *bs*. This, as has been noted elsewhere, may be put down to several causes. In the first place, both are formed at a very early stage of the plant's growth—before the general elongating stage has been reached—the plant is small and thin and has comparatively few roots and leaves. In the second place, cases are not infrequently met with in which, *as* having died, one or more of the *bs* become facultative *as*, and the energies of these are devoted rather to branching than to increase in thickness. Thirdly, there are more *bs* on an *a* than *cs* on a *b*, and, as we have seen, this leads to a tailing off of the later-formed *bs*, when the energy of the main shoot is waning (*cf.* p. 107). Lastly, other irregularities occur owing to the deaths of *as* and the consequent relative numbers of *as* and *bs* in a plant. Thus, in *Kharwi*, the thinnest of the Mungo group, 3 *as* and 19 *bs* were measured, whereas in *Hemja*, the thickest cane in the group, there are 15 *as* and 27 *bs*. In taking

all the *a*s and all the *b*s of the group, we thus find that the latter are penalized as to average thickness. But the fact remains, whatever its cause may be, that there is often little difference between the thickness of the main shoot and its immediate branches. And, in dividing up the canes in a clump, both must be classed as early in their general character. The *c*s and *d*s are sharply separated off from the *a*s and *b*s as thick, late canes, and can be readily picked out at harvest by this and other characters.

In the Thick cane group there is a curious exception. While the six varieties examined at Coimbatore and the dry land canes at Nellikuppam show a considerable increase in thickness of the *b*s over the *a*s, this is not the case in the *wet land* plants at the latter place. In these the *a*s are the thickest and there is a general decrease in thickness as we pass to the higher branchings. The *Red Mauritius* at the Cane-breeding Station (and indeed at Nellikuppam on the dry land) are more or less in line with the other varieties. The figures for *Red Mauritius* on the farm, for instance, are *a* 270, *b* 312, *c* 347. We may, in the absence of any further light on the case, merely record the fact here and regard it as an exception which may indicate some peculiarity in wet land conditions.

Average thickness of cane at 2′ from the base, in mm.

Groups	ALL THE BRANCHES OF THE SAME ORDER TAKEN TOGETHER															
	In each plant						In each variety					In each group				
	a	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*
Saretha	159	166	178	192	204	...	159	164	174	194	204	160	166	175	188	204
Pansahi	166	166	189	223	284	...	166	165	185	224	284	166	165	185	224	284
Mungo	187	190	210	204	224	...	187	191	209	207	224	196	193	204	204	224
Sunnabile	189	192	209	262	...	...	189	190	208	262	...	186	188	220	262	...
Nargori	151	156	175	213	...	...	152	156	171	211	...	150	154	167	207	...
Thick canes	263	282	298	345	...	...	...	...	...	...	...	...	...		...	...
Red Mauritius, Nellikuppam Dry land	294	304	305	299	314	...	...	...	...	...	...	...	...	...	...	...
" " Wet land	290	274	261	270	268	...		...	...		...	...	...	...	...	...
Unclassified indigenous	164	173	208	251	...	...	...	...	...		...	...	...	...	...	...
Rogues	170	196	211	210	215	...		...	...	...	...	...	...		...	...
Crosses, Vellai × Saccharum spontaneum	158	177	231	...	...	...		...		...	...	...	...	...	...	...
Saccharum spontaneum	73	77	83	88	79	88	...	...	...	...	...	...	...	...	...	...
Saccharum arundinaceum	153	172	209	237	237	...	...	...	...	...	...	...	...	...	...	...
Average of all the groups	177	187	207	228	219	88	...	...	...	...	...	...	...	...	...	...

The work of measuring the thickness of the cane branches of different orders has not always been altogether simple, and has given rise to a series of

"side-issues." Such are, the not infrequent thickening upwards of the early canes and narrowing upwards of late ones; the sometimes enormous thickness at the base of late canes, especially within the region of curvature; the ovalness of some canes and the tereteness of others, and, lastly, the curious case in a few varieties where this ovalness is very pronounced, but in the lateral instead of the median plane, a general flattening of the stem at the base soon to give way to normal tereteness. But these deviations have little or no effect on the general increase in thickness as we proceed to branches of higher order.

Summarizing the results recorded in the last few pages, we see that there is a marked difference between the early and late formed stems in the sugarcane plant. The main shoot has a longer basal portion than its branches, but, owing chiefly to curvature, this portion becomes longer again in the branches of the second and third orders. The average length of joints in the lower part of the cane is less in the main shoot than its branches, and in these again than in the branches of higher orders. With few exceptions the same holds good of the thickness of the cane. For the separation of the canes in a clump, we thus have a series of characters whereby we can distinguish the early and late canes, without the necessity of the tedious process of dissection, there being a marked contrast between the *a*s and *b*s, on the one hand, and the *c*s and *d*s on the other, differences which are so striking that we can with comparative certainty apply the test to the general mass of canes belonging to one variety in the mill yard, and by this means are in a position to make further studies on the milling properties and sugar content of the branches of different order.

(7) Rate of maturing in different varieties and groups.

In passing through the various plots of cane varieties growing on the farm, it is at once obvious that, in the early stages, there is a great difference in the rate of cane formation. While some, like *Saretha*, show cane formation very early, others, like *Dhor*, grow very slowly at first, and do not show any canes for months afterwards. This difference is largely cloaked in North Indian canes by the persistence of the leaf sheaths, but the swelling canes often split these at the base while still attached, and it is quite easy to strip off one or two where this is not the case. But it is difficult to place this difference before the reader, and various attempts have been made, as will be seen below, to make it clearer. There were comparatively few dissections among young canes in the 1916-17 crop, but the results were sufficiently distinctive to make it desirable to extend the series to all the indigenous classes. Two clumps

were accordingly taken for each of the varieties in the dissection plot and these were examined at 3–5 months from planting. The more rapidly maturing groups were taken first, as explained on p. 112. Thus, the Saretha group was examined 106–112 days after planting, Pansahi 113–120, Nargori 120–126, Mungo 126–132, Sunnabile 133–143, and Thick canes 149–152. These were the main groups it was desired to compare. The wild Saccharums, of which one species showed poor accommodation to the cultivated land, were examined at 120–156 days, while the Unclassified indigenous canes, the Crosses and Rogues, being less important, were taken at the end of the series. It transpired that the arrangement was not ideal; the last named varieties should have been dissected earlier, and certain other alterations would have been desirable. This varying age of the plants dissected has introduced complications and must be held in view in the comparisons. In two cases, the early development was so poor that additional clumps were dissected at the end of the period, and a study of the results obtained will give some idea as to the rapidity of change at this stage of growth. *Dhor* was dissected at 142 and 156 and *Khari* at 110 and 156 days, namely, the beginning and the end of the work. The following table gives the canes and shoots formed per clump in these two varieties at the dates given :—

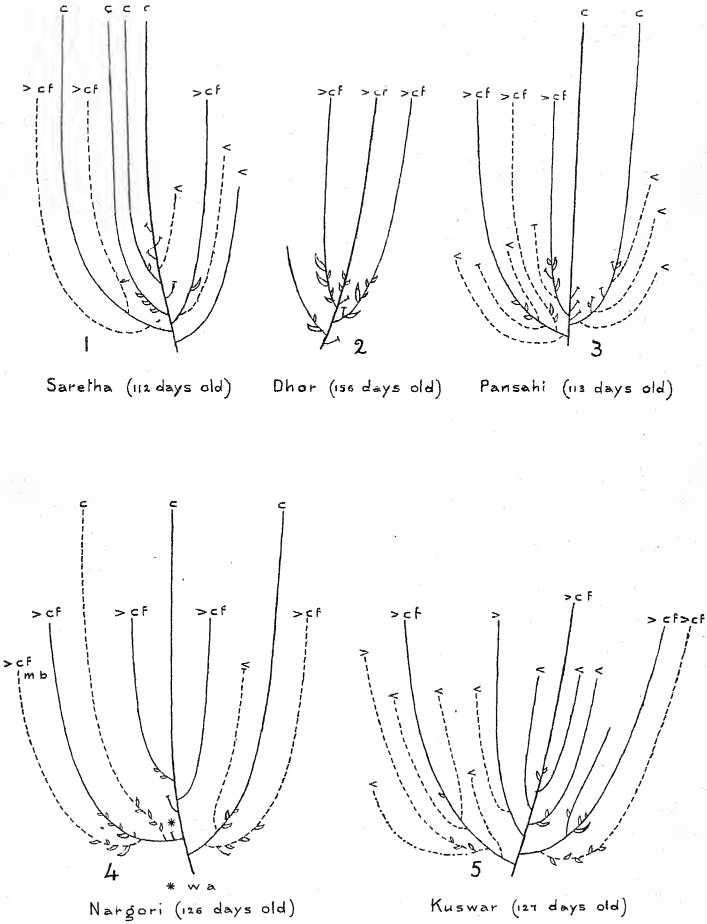
Dhor	..	2	clumps with	4	plants	142	days old	3·0	canes	2·0	shoots
	..	2	,,	,, 4	,,	156	,, ,,	5·3	,,	2·5	,,
Khari	..	2	clumps with	6	plants	110	days old	3·5	canes	21	shoots
	..	2	,,	,, 7	,,	156	,, ,,	14·0	,,	7	,,

The word "canes" in the list indicates cane-forming shoots, and this is judged by the presence of hardened rind in one or more of the basal joints. In the diagrams prepared from the dissections, such cane-forming shoots are indicated by the bases being in ink, the rest of the diagrams being in pencil. Green shoots, not cane-forming, are simply classed as shoots and burst buds and deaths are added as usual. A further distinction is introduced in all the shoots, whether cane-forming or not, in that they are separated into two classes, according as they were over or under 3′ in length, and this is indicated in the diagrams by the signs $>$ and $<$, as well as the general length of the line for the branch. All the branches are separated, as usual, into *a*s, *b*s, *c*s, etc. It is obvious that, from a consideration of such a diagram and the formula describing it, a very fair idea can be obtained as to the stage of development of any plant or clump. An example for each group is given in the figures on Plate XIX, where, however, the pencil marks are omitted, full grown shoots are marked c, and half grown,

cane-forming shoots cf. The other conventions are those adopted in the diagrams of full grown plants.

Some 275 plants were dissected in 1917-18, and diagrams recorded of their branching systems. These have been averaged according to variety and group, but the results, although generally illuminating, show certain incongruities, obviously requiring explanation. Thus, *Dhaulu*, *Naanal* and *Mojorah* showed enormous and rapid development, which would hardly be expected in the Sunnabile group. It was observed that each of the six clumps dissected in these varieties consisted of a single plant, the two other buds of the set not having germinated, and it is obviously unsafe to compare such single plants with those formed two or three together. On the other hand, in the Mungo group, owing to the closeness of the joints, as many as 7 or, in one case, 11 plants arose from one set, and these naturally showed, on the average, very few branches (Pl. XVI). The whole series was therefore again averaged, this time as to the numbers of canes, shoots, etc., per clump or "hole," and this gave much more satisfactory results.

It was soon observed that there were great variations in the development of the members of certain groups and it becomes doubtful if the six varieties selected suitably represent them. Owing to its rapid growth, the first series dissected was the Saretha group, and it was obvious that *Khari*, *Ganda Cheni* and *Hullu Kabbu* were much behind the rest, although it was known that *Chin* and *Saretha* did not grow well on the farm, while *Cheni* and *Hullu* were quite at home. This emphasizes the subdivision made in this group in Memoir III, into the Brown or Katha and the Green or Mesangan sections, as the same subdivision is seen in the rate of maturing. Less equal subdivisions show themselves in the Sunnabile group where *Dhor* and *Sunnabile* were much behind the rest, in the Mungo group where *Kharwi* shows as great a difference in the opposite direction from its companions, and in the Thick canes where the possibly indigenous *Magh* and *Vendamukhi* are considerably behind *Java*, *Yerra* and *Red Mauritius*. The groups in the table are arranged in the order of dissection.



Diagrams of branching in plants 3-4 months old, in the five groups of indigenous Indian canes. These give a general idea of the conventions used in the 275 diagrams prepared and also give some idea of the relative rate of cane formation in the different groups.

Analysis of clumps in different groups to compare their rate of maturing, 1917-18.

	No. of clumps	Days old	CANE-FORMING SHOOTS (>+<)					SHOOTS NOT CANE-FORMING (>+<)					BURST BUDS					DEATHS					RUNNERS
			a	*b*	*c*	*d*	Total	*a*	*b*	*c*	*d*	Total	*b*	*c*	*d*	*e*	Total	*a*	*b*	*c*	*d*	Total	
Saretha Green	8	108	1·7+0	2·5+0	0·2+0	...	4·3+0	...	1·7+2·3	1+9·2	0+0·5	2·8+12	0·8	6·5	2·7	...	10	...	1·8	2·0	0·5	4·3	0·5
Saretha Brown	6	110	2·7+0	8·0+0	3·2+0·2	0·2+0	14+0·2	...	0·8+2·8	0·7+4·3	0+0·2	1·5+7·3	1·3	7·3	2·0	...	10·7	...	2·5	3·2	1·5	7·2	0·7
Pansahi ...	12	116	2·2+0	6·7+0·1	2·8+0	0+0·2	11·7+0·2	...	0·2+2·3	0·2+4·7	0·1+7·4	0·5+8·4	0·6	15·8	5	0·6	22	0·1	1·4	2·2	1·2	5·0	0·3
Nargori ...	12	123	2·2+0	6·5+0·3	1·6+0·1	...	10·2+0·4	...	0·1+1·8	0+1·2	...	0·1+3	7·5	10·9	1·8	...	20·2	0·2	2·2	3·7	0·3	6·4	0
Mungo ...	12	129	2·8+0·2	6·1+0·7	3·6+0·7	0·2+0·4	12·7+2	0·2+0·2	1·1+7·9	0·7+10·5	0+2·5	2·1+21·4	6·7	25·3	18·9	2·8	53·8	0·6	2·8	3·2	1·1	7·7	0
Sunnabile	14	138	1·3+0·7	3·8+2·8	2+1·1	0·1+0·3	7·2+5	...	0·2+1·4	0+1·3	...	0·2+2·7	8·4	27·3	4·3	0·6	40·7	0·2	2·9	2·2	0·6	5·8	0
Unclassified indigenous	12	145	1·9+0·6	4·1+5·5	0·6+2·2	0+0·2	6·6+8·5	...	0+0·3	0+0·4	...	0+0·7	7·4	28	4·2	0·1	39·7	0·2	3·5	5·3	0·8	7·8	0
Thick ...	10	150	1·0+0·8	1·1+5·7	0+1·5	...	2·1+8·1	...	0+2·7	0+2·4	...	0+5·1	5	23·7	3·1	...	31·7	...	4·1	6·2	0·4	10·7	0
Rogues ...	4	154	0·5+2·5	1+12	0+12	0+1	2+27·5	...	0+4	0+9·5	...	0+13·5	5	14	5	...	24	...	8·5	11	0·5	20	0
Crosses, Vellai × Saccharum spontaneum	4	156	2·5+0	7+2·7	2·5+4·7	...	14+7·5	...	0+2·5	0+4·2	...	0+6·7	0·5	9·2	10·2	...	20	...	2·7	5·7	3·5	12	0
Saccharum spontaneum	4	134	0·5+1·2	1·2+4·5	0·5+5	0+0·5	2·2+11·2	...	0+2	0+2	0+0·7*e*	0+4·7	0·7	1·0	0·5	...	2·2	0·2	3·2	5·2	0·5	9·2	2·2

With this table before us, the question naturally arises as to how we can use it for determining the rate of maturing. We may do so in a variety of ways. We may compare the average number of canes per clump in each group or section; we may calculate the number of canes in the total number of shoots; we may contrast the canes over 3′ with those under that length; we may do the same with the total number of shoots; and, lastly, we may compare the number of cane-forming shoots at 3–5 months with the average number formed at harvest in the same plots. There are, however, objections to all of these methods, even when the relative ages of the plants at the time of dissection have been allowed for. In the first, we neglect the inherent tillering capacity of the different varieties, in the second the Sunnabile and Nargori groups are favoured because of the very small number of small shoots which are developed in them, in the third and fourth we discriminate in favour of forms with long canes such as *Saretha* as against the short-caned forms such as *Mungo*, and in the last we neglect the habitual deaths which take place during the life of the plant and which are so numerous in the Thick canes, for instance, that there are actually more canes forming per clump at 5 months than there are at harvest. But something may be learnt, with proper safeguards, from a study in each of these directions, and the results have been grouped in the following table. In this, besides the averages for each group, the brown and green sections of Saretha are given separately, in the Sunnabile group *Dhor* and *Sunnabile* are taken as a sub-section (Dhor) and compared with the rest (Dhaulu), and *Kharwi* is similarly treated separately in the Mungo group. The other groups appear to be more homogeneous, but, in the Thick canes, *Magh* and *Vendamukhi*, as noted above, are very much behind *Yerra*, *Java* and *Red Mauritius*. In each of the arrangements 1–5, the groups are placed in order of development from top to bottom.

Arrangements of the different groups of cane dissected according to different evidences of relative maturing (see p. 130).

CANES PER CLUMP		CANES TO TOTAL SHOOTS			CANES > TO < 3′			TOTAL SHOOTS > TO < 3′			CANES AT 4 MONTHS TO CANES AT HARVEST		
Arrangement No. 1	Canes	Arrangement No. 2	Canes	Total shoots	Arrangement No. 3	> 3′	> 3′	Arrangement No. 4	> 3′	< 3′	Arrangement No 5	4 months	Harvest
Sunnabile (Dhaulu)	15·2	Unclassified indigenous	15·1	15·8	Saretha (Green)	4·3	0	Nargori ...	10·3	3·4	Thick ...	12·4	8·7
Unclassified indigenous	15·1	Sunnabile (Dhaulu)	15·2	18·1	Saretha ...	9·1	0·1	Saretha (Brown)	15·5	7·5	Sunnabile (Dhaulu)	15·3	18·0
Saretha (Brown)	14·2	Nargori ...	10·6	13·7	Saretha (Brown)	14·0	0·2	Mungo (Kharwi)	25·0	13·5	Sunnabile ...	12·2	17·1
Mungo (Kharwi)	13·7	Sunnabile ..	12·2	15·1	Pansahi ...	11·7	0·2	Sunnabile (Dhaulu)	10·6	7·5	Saretha (Brown)	14·2	24·0
Saccharum spontaneum	13·2	Saccharum spontaneum	17·4	18·1	Nargori ...	10·2	0·4	Pansahi ...	12·2	8·6	Unclassified indigenous	15·1	25·0
Sunnabile ...	12·2	Thick ...	10·2	15·2	Mungo (Kharwi)	24·5	2·0	Saretha ...	11·3	7·7	Nargori ...	10·6	17·0
Pansahi ...	11·9	Sunnabile (Dhor)	6·2	9·2	Mungo ...	12·7	2·0	Sunnabile ...	7·7	7·7	Pansahi ...	11·9	21·0
Nargori ...	10·6	Mungo (Kharwi)	26·7	28·7	Mungo (rest) ...	10·2	2·0	Unclassified indigenous	6·6	9·2	Sunnabile (Dhor)	6·2	15·0
Thick canes ...	10·2	Saretha (Brown)	14·2	23·0	Sunnabile (Dhaulu)	10·4	4·9	Mungo ...	14·8	23·4	Saretha ...	9·2	23·0
Saretha ...	9·2	Pansahi ...	11·9	20·8	Sunnabile ...	7·2	5·0	Saretha (Green)	7·1	12·0	Mungo (Kharwi)	13·7	37·0
Mungo ...	7·3	Saretha ...	9·2	21·0	Unclassified indigenous	6·6	8·5	Mungo (rest) ...	12·6	25·3	Saccharum spontaneum	13·2	41·0
Sunnabile (Dhor)	6·2	Mungo ...	14·7	38·2	Thick ...	2·1	8·1	Thick ...	2·1	13·2	Mungo ...	7·3	28·4
Mungo (rest) ...	6·1	Mungo (rest) ...	12·2	27·4	Saccharum spontaneum	2·2	11·2	Saccharum spontaneum	2·2	15·9	Mungo (rest) ...	6·1	27·0
Saretha (Green)	4·3	Saretha (Green)	4·3	19·1	Sunnabile (Dhor)	1·0	5·2	Sunnabile (Dhor)	1·0	8·2	Saretha (Green)	4·3	22·0

From a study of this table we get the following order of development as judged by the various comparisons in the columns 1–5. Sunnabile (Dhaulu), Saretha (Brown), Nargori, Unclassified indigenous, Sunnabile, Mungo (Kharwi), Pansahi, Saretha, Thick canes, *Saccharum spontaneum*, Mungo, Saretha (Green), Sunnabile (Dhor), Mungo (rest). But we have, in addition, to consider the ages of the plants dissected. It is thus seen that the position of Sunnabile (Dhaulu) at the head of the table must be qualified, firstly, by the fact that in these members of the section, only a single plant developed in each clump, presumably assisting in rapid maturing, and, secondly, that the dissections were made late (4 weeks after the Brown section of Saretha), because of the slow development of *Dhor* and *Sunnabile*. Saretha (Brown) is obviously the quickest of all in maturing. Similarly, the juxtaposition of the Saretha and Thick cane groups, examined at 109 and 150 days respectively, indicates that the latter are much later in development than the former. So the Mungo group, excepting *Kharwi*, are very late indeed, being near the bottom of the list, although dissected moderately late (129 days). But the method is interesting, although unsatisfactory for generalizations.

The only way in which these various defects can be avoided is to take the groups and sections separately and compare them with the rest in the following manner. Saretha (Brown) is ahead of Pansahi, although examined a week earlier. There are more canes formed, and, in these, there is a slightly larger proportion of canes over than under 3′ in length; there are practically the same number of immature shoots, but in these too there is a slight excess of the shoots over 3′ long in Saretha; there are only half the number of buds and there are slightly more deaths. If the tillering power of the two groups is considered, there is a larger proportion of canes formed in Saretha in 110 days than in Pansahi in 116. It may therefore be safely concluded that the Brown section of the Saretha group is earlier in its development on the farm than the Pansahi group. The same method may be applied all through and, as a result, we can place the groups roughly in the following order :—

Early maturing, Saretha (Brown), Nargori, Pansahi, Saretha, Sunnabile (Dhaulu), Mungo (Kharwi);

Moderately early maturing, Various indigenous, Saretha (Green), *Saccharum spontaneum*, Thick canes;

Late maturing, Sunnabile, Mungo, Mungo (rest) and Sunnabile (Dhor).

The full table of analyses of the different varieties is annexed, the figures in each group being the averages obtained for each clump.

Average formulæ of clumps in varieties and groups.

	Clumps and plants	Days old	Cane-forming shoots > + <					Shoots not cane-forming > + <					Burst buds					Deaths					Runners
			a	b	c	d	Total	a	b	c	d	Total	b	c	d	e	Total	a	b	c	d	Total	
Saretha group, Green section																							
Ganda Cheni	II 4	106	2·0 +	2·5+	0·5+	...	5·0+	...	2·0+ 2·5	+ 8·0	+ 0·5	2·5+11	1·0	10·0	2·0	...	13·0	...	0·5	1·0	...	1·5	1·0
Hullu Kabbu	II 5	108	2·5 +	2·0+	...	...	4·5+	...	0·5+ 2·5	2·5+ 3·5	+ 1·0	3·0+ 7	1·0	5·0	5·0	...	11·0	..	2·5	1·0	...	3·5	0·5
Khari	II 6	110	0·5 +	3·0+	...	...	3·5+	...	2·5+ 2·0	0·5+16·0	...	3·0+18	0·5	4·5	1·0		6·0	...	2·5	4·0	1·5	8·0	...
Average of green section ...	...	...	1·7 +	2·5+	0·2+	...	4·3+	...	1·7+ 2·3	1·0+ 9·2	+ 0·5	2·8+12	0·8	6·5	2·7	...	10·0	..	1·8	2·0	0·5	4·3	0·5
Saretha group, Brown section																							
Chin	II 5	107	2·5 +	4·5+	1·0+	...	8·0+	...	2·0+ 3·5	2·0+ 6·0	+ 0·5	4·0+10	1·0	3·0	2·5	...	6·5	...	0·5	1·0	1·0	2·5	1·0
Katha	II 4	111	2·0 +	6·5+	4·0+ 0·5	0·5+	13·0+ 0·5	...	0·5+ 1·0	+ 0·5	...	0·5+ 1·5	0·5	0·5	1·0	...	2·0	...	1·5	1·5	3·5	6·5	1·0
Saretha	II 7	112	3·5 +	13·0+	4·5+	..	21·0+	...	+ 4·0	+ 6·5	...	+10·5	2·5	18·5	2·5	...	23·5	...	5·5	7·0	...	12·5	...
Average of brown section ...	...	...	2·7 +	8·0+	3·2+ 0·2	0·2+	14·0+ 0·2	..	0·8+ 2·8	0·7+ 4·3	+ 0·2	1·5+ 7·3	1·3	7·3	2·0	...	10·7	...	2·5	3·2	1·5	7·2	0·7
Pansahi group																							
Pansahi	II 3	113	1·5 +	3·5+	1·0+	+ 1·0	6·0 + 1·0	...	+ 1·0	0·5+ 7·0	+ 3·0	0·5+11·0	...	4·0	4·0	1·5	9·5	...	1·5	4·0	0·5	6·0	...
Chynia	II 6	117	3·0 +	8·5+	1·0+	...	12·5+	...	0·5+ 1·5	0·5+ 2·0	...	1·0+ 3·5	...	30·5	4·5	.	35·0	...	...	0·5	1·5	2·0	...
Yuba	II 5	115	2·5 +	7·0+ 0·5	4·0+	..	13·5+ 0·5	..	+ 4·0	0·5+ 7·5	+ 2·0	0·5+13·5	2·5	22·5	11·0	0·5	36·5	...	3·5	2·0	1·0	6·5	1·0
Maneria	II 4	114	2·0 +	5·5+	5·0+	..	12·5+	...	+ 4·0	+ 2·5	0·5+ 3·5	0·5+10·0	1·0	6·0	3·5	1·5	12·0	...	2·5	2·5	3·0	8·0	...
Kahu	II 5	120	2·0 +	8·0+	2·0+	...	12·0+	...	0·5+ 3·0	+ 5·5	...	0·5+ 8·5	...	19·5	4·5	...	24·0	0·5	0·5	2·5	...	3·5	...
Sada Khajee	II 4	118	2·0 +	8·0+	4·0+	...	11·0+	...	+ 0·5	+ 3·5	...	+ 4·0	...	12·5	2·5	...	15·0	...	0·5	2·0	1·5	4·0	1·0
Average of group	...	...	2·2 +	6·7+ 0·1	2·8+	+ 0·2	11·7+ 0·2	...	0·2+ 2·3	0·2+ 4·7	0·1+ 1·4	0·5+ 8·4	0·6	15·8	5·0	0·6	22·0	0·1	1·4	2·2	1·2	5·0	0·3
Nargori group																							
Baroukha	II 5	120	2·5 +	2·0+	1·5+	...	6·6+	...	+ 4·5	+ 1·0	..	+ 5·5	2·5	5·0	2·5	...	10·0	...	2·5	1·0	..	3·5	...
Kewali	II 5	125	2·5 +	3·5+	...	...	6·0+	...	0·5+ 1·0	...	...	5·0+ 1·0	4·5	7·0	...	..	11·5	...	4·0	2·0	...	6·0	...
Katai	II 6	124	3·0 +	8·0+ 1·0	...	...	11·0+ 1·0	...	+ 1·0	+ 1·0	...	+ 2·0	19·0	1·0	...	...	20·0	...	05	...	...	0·5	...
Newra	II 6	122	2·0 +	11·5+	2·0+	...	15·5+	...	+ 3·0	...	...	+ 3·0	2·5	29·5	4·0	..	36·0	1·0	2·0	3·5	...	6·5	...
Nargori	II 4	126	2·0 +	8·5+ 1·0	4·5+ 0·5	...	15·0+ 1·5	...	+ 1·0	+ 2·5	...	+ 3·5	16·5	17·5	1·0	...	35·0	...	2·0	12·0	2·0	16·0	...
Sararoo	II 3	124	1·0 +	5·5+	1·5+	...	8·0+	...	+ 0·5	+ 2·5	...	+ 3·0	...	5·5	3·5	...	9·0	0·5	2·0	3·5	...	6·0	...
Average of group	...	...	2·2 +	6·5+ 0·3	1·6+ 0·1	...	10·2+ 0·4	...	0·1+ 1·8	+ 1·2	..	0·1+ 3·0	7·5	10·9	1·8	...	20·2	0·2	2·2	3·7	0·3	6·4	...
Mungo group																							
Rheora	II 11	129	3·5 +1·0	2·5+ 1·0	0·5+ 0·5	...	6·5+ 5·5	...	+12·0	+ 5·5	...	+17·5	18·0	46·5	...	...	64·5	1·0	6·0	5·0	...	12·0	...
Mungo	II 7	128	2·0 +	6·5+	1·0+	...	9·5+	0·5+	1·0+10·5	0·5+15·0	+ 1·5	2·0+27·0	2·5	23·5	18·0	...	44·0	1·0	1·5	3·5	...	6·0	...
Kuswar	II 6	127	2·5 +	7·5+	6·0+ 0·5	..	16·0+ 0·5	+ 0·5	3·0+ 6·5	2·5+17·5	+ 3·0	5·5+27·5	2·5	16·5	15·0	...	34·0	...	2·0	1·5	2·0	5·5	...
Hemja	II 17	126	7·0 +	6·0+	...	..	13·0+	1·0+	2·0+13·5	+ 3·0	..	3·0+16·5	10·0	22·0	...		32·0	0·5	6·0	6·0	0·5	13·0	...
Katara	II 7	132	+0·5	3·0+	3·0+ 2·5	+ 1·0	6·0+ 4·0	+ 0·5	0·5+ 1·5	1·0+15·0	+ 7·5	1·5+28·0	2·0	11·5	36·0	12·0	61·5	0·5	0·5	1·0	2·5	4·5	...
Kharwi	II 5	131	2·0 +	11·0+	11·0+ 0·5	1·0+ 1·5	25·0+ 2·0	...	+ 0·5	0·5+ 8·5	+ 3·0	0·5+12·0	5·5	32·0	44·5	5·0	87·0	0·5	1·0	2·5	1·5	5·5	...
Average of group	...	...	2·8 +0·2	6·1+ 0·7	3·6+ 0·7	0·2+ 0·4	12·7+ 2·0	0·2+ 0·2	1·1+ 7·9	0·7+10·8	+ 2·5	2·1+21·4	6·7	25·3	18·9	2·8	53·8	0·6	2·8	3·2	1·1	7·7	...
Unclassified indigenous																							
Ikri	II 6	143	1·5 +1·0	3·0+ 6·0	+ 2·5	..	4·5+ 9·5	...	...	...	..	...	6·5	48·5	6·5	...	61·5	0·5	6·5	5·0	...	12·0	...
Khelia	II 6	143	2·5 +	6·0+ 7·5	0·5+ 2·0	...	9·0+ 9·5	...	...	+ 0·5	...	+ 0·5	9·0	5·3	4·5	...	66·5	0·5	1·5	2·5	1·5	6·0	...
Teboe Monjet	II 5	116	2·5 +	6·0+ 2·5	2·5+ 2·0	...	11·0+ 4·5	...	+ 1·0	+ 0·5	...	+ 1·5	10·0	...	...	...	10·0	...	1·5	1·0	...	2·5	...
Khagri	II 5	145	1·0 +1·5	1·0+ 4·5	+ 1·5	...	2·0+ 7·5	..	+ 0·5	+ 1·0	...	+ 1·5	8·5	18·5	4·0	...	31·0	...	4·0	5·0	1·0	10·0	...
Kassoer	II 5	147	2·5 +	4·5+ 6·0	0·5+ 2·0	+ 1·0	7·5+ 9·0	...	...	+ 0·5	...	+ 0·5	6·5	25·0	9·0	...	40·5	...	4·0	2·5	1·0	7·5	...
Dhaulu of Phillaur	II 5	147	1·5 +1·0	4·0+ 6·5	+ 3·5	...	5·5+11·0	...	+ 0·5	...	...	+ 0·5	4·0	23·5	1·5	1·0	30·0	...	3·5	4·0	1·5	9·0	...
Average of set	...	...	1·9 +0·6	4·1+ 5·5	0·6+ 2·2	+ 0·2	6·6+ 8·5	...	+ 0·3	+ 0·4	...	+ 0·7	7·4	28·0	4·2	0·1	39·7	0·2	3·5	3·3	0·8	7·8	...
Sunnabile group																							
Dhor	II 4	142	+1·5	+ 1·5	...	...	+ 3·0	...	+ 2·0	...	...	+ 2·0	5·5	10·5	...	...	16·0	0·5	3·5	1·0	...	5·0	...
Sunnabile	II 6	138	1·5 +1·5	0·5+ 6·0	...	...	2·0+ 7·5	...	+ 3·5	+ 0·5	...	+ 4·0	7·0	35·0	...	...	42·0	...	4·0	2·5	...	6·5	...
Bansa	II 6	143	1·0 +1·5	2·0+ 6·5	2·0+ 3·0	+ 1·5	5·0+12·5	...	...	+ 1·5	...	+ 1·5	10·5	40·5	11·5	3·5	66·0	0·5	4·0	2·5	1·5	8·5	...
Mojorah	II 2	140	1·0 +	3·5+ 2·5	2·0+ 1·5	...	6·5+ 4·0	...	...	+ 1·0	...	+ 1·0	2·5	19·5	13·0	...	35·0	...	1·5	2·5	1·5	5·5	...
Naanal	II 2	134	3·5 +	10·5+ 0·5	1·0+ 0·5	...	15·0+ 1·0	...	1·0+ 2·0	+ 0·5	...	1·0+ 2·5	8·0	40·0	1·5	...	49·5	...	2·0	2·0	...	4·0	...
Dhaulu	II 2	133	1·0 +	6·5+	7·0+ 1·5	0·5+ 0·5	15·0+ 2·0	...	+ 1·0	+ 4·5	...	+ 5·5	17·0	18·5	...	..	35·5	...	2·5	2·5	2·0	7·0	...
Average of group	...	...	1·3 +0·7	3·8+ 2·8	2·0+ 1·1	0·1+ 0·3	7·2+ 5·0	...	0·2+ 1·4	+ 1·3	...	0·2+ 2·7	8·4	27·3	4·3	0·6	40·7	0·2	2·9	2·2	0·8	6·1	...
Thick canes																							
Magh	II 3	152	+1·5	+ 4·5	...	...	+ 6·0	...	+ 4·5	+ 0·5	...	+ 5·0	5·5	21·0	...	...	26·5	...	1·5	2·5	...	4·0	...
Vendamukhi	II 4	150	0·5 +1·5	+ 6·5	...	...	0·5+ 8·0	...	+ 7·0	+ 8·5	...	+15·5	2·5	16·0	1·0	...	19·5	...	1·0	5·5	...	6·5	...
Java	II 3	149	1·5 +	1·5+ 5·5	+ 1·5	...	3·0+ 7·0	...	...	+ 0·5	...	+ 0·5	5·5	34·5	2·5	...	42·5	...	6·5	5·5	...	12·0	...
Red Mauritius	II 6	149	2·5 +0·5	2·0+10·0	+ 1·0	...	4·5+11·5	...	+ 2·5	+ 2·5	...	+ 5·0	9·0	38·0	...	...	47·0	...	7·0	10·5	...	17·5	...
Yerra	II 6	152	1·5 +1·5	3·0+ 8·0	+ 6·5	...	4·5+16·0	...	+ 2·0	+ 2·5	...	+ 4·5	7·5	32·5	15·0	...	55·0	...	8·5	13·0	2·5	24·0	...
Average of group	...	...	1·0 +0·8	1·1+ 5·7	+ 1·5	...	2·1+ 8·1	...	+ 2·7	+ 2·4	...	+ 5·1	5·0	23·7	3·1	...	31·7	...	4·1	6·2	0·4	10·7	...
Rogue 5,300 in striped Mauritius flat	II 6	154	0·5 +2·5	1·0+12·0	+12·0	+ 1·0	2·0+27·5	...	+ 4·0	+ 9·5	...	+13·5	5·0	14·0	5·0	...	24·0	...	8·5	11·0	0·5	20·0	...
Cross 2,867, Vellai × Saccharum spontaneum	II 4	156	2·0 +	4·0+ 4·0	+ 4·5	...	6·0+ 8·5	...	+ 3·0	+ 6·5	...	+ 9·5	1·0	10·5	5·0	...	16·5	...	2·0	2·0	0·5	4·5	...
Cross 10,801, Vellai × Saccharum spontaneum	II 6	156	3·0 +	10·0+ 1·5	5·0+ 5·0	...	18·0+ 6·5	...	+ 2·0	+ 2·0	...	+ 4·0	...	8·0	15·5	...	23·5	...	3·5	9·5	6·5	19·5	...
Saccharum spontaneum (Coimbatore)	II 4	148	1·0 +1·0	2·5+ 4·0	1·0+ 6·5	+ 1·0	4·5+12·5	...	...	...	+ 1·5e	+ 1·5	1·0	1·5	1·0	...	3·5	...	5·0	7·0	1·0	13·0	4·5
Saccharum spontaneum (Dacca)	II 4	120	+1·5	+ 5·0	+ 3·5	...	10·0+	...	+ 4·0	+ 4·0	...	+ 8·0	0·5	0·5	...	...	1·0	0·5	1·5	3·5	...	5·5	...
Average of Saccharum spontaneum	...	...	0·5 +1·2	1·2+ 4·5	0·5+ 5·0	+ 0·5	2·7+11·2	...	+ 2·0	+ 2·0	+ 0·7e	+ 4·7	0·7	1·0	0·5	...	2·2	0·2	3·2	5·2	0·5	9·2	2·2

(8) General notes on the characters of the groups and their mode of branching.

It will be impossible within reasonable limits to discuss the many interesting facts observed in the dissections of the cane clumps of the different varieties in each group. The diagrams and measurements of the individual plants are added to the already large mass of notes on the morphology of canes collected in the office files. A few general notes are here given on the characters of branching in each group and a selection has been made of a few more or less typical diagrams and photographs to illustrate its general character. For photographs, we have had to rely entirely on 1916-17 dissections, because, from pressure of work and the high price of materials, we were unable to photograph the dissected plants in the second year. The main shoot *a* can be distinguished in these photographs by a white paper band fastened round it. As the full scheme of diagrams was not developed until 1917-18, it has not always been easy to give the full diagrams of the particular plants photographed, although this has been done where possible. As an instance of the method, Plates XXVIII–XXX may be referred to. In Plate XXVIII, a clump of the dwarf canes of *Hemja*, in the Mungo group, has been photographed as it reached the laboratory; Plate XXIX gives photographs of the four dissected plants in this clump, and in the lower half of Plate XXX the diagrams of the four plants are reproduced. There are few photographs available of the Thick canes, as less attention was paid to this class in the first year, but, besides a dissection of *Java*, a picture is reproduced of a ratooned *Red Mauritius* cane, and its diagram is appended. In the wild Saccharums, photographs are given of *S. Munja*, *S. arundinaceum*, and the two chief varieties of *S. spontaneum* (Pl. XXXIV); further pictures may be found in Plate II of Memoir III and Plate XXI of Memoir II. *Saccharum Narenga* is illustrated on Plates IX and X of Memoir II and needs no repetition. For fuller illustrations of these wild Saccharums, reference may be made to the excellent monograph by Hole in the Indian Forest Memoirs.[1] The diagrams of *Saccharum Munja* and *Saccharum Narenga* are less instructive, in that these species do not form canes in the strict sense, but their grass-like habit may be inferred from the diagrams given on Plate XXXVII, where the "canes" refer to shoots forming solid canes at their bases.

Saretha Group.

The Saretha group is somewhat difficult to describe without going into great detail, as it consists of two well-marked sections, the main characters

[1] Hole, R. S. On some Indian Forest Grasses and their Oecology. *Ind. For. Mem., For. Bot. Ser.*, Vol. I, Part 1, 1911.

of which have been discussed in Memoir III. These sections are separated, in the first place, by having red-brown and green stems at maturity. Of the members dealt with in this paper, *Katha* in the Punjab, and *Chin* and *Saretha* in the western United Provinces belong to the first section; the second section includes *Khari*[1] in Bengal, *Hullu Kabbu* on the western coast of the Peninsula and *Ganda Cheni* in Mysore; the distribution of the two sections is thus seen to be geographical, the northern members being thinner and more primitive. The Green section of the Saretha group appears to approach the Sunnabile group in many particulars. As might be expected, the forms indigenous to the Peninsula are much more at home on the Cane-breeding Station, and this renders the comparison of the two sections, as regards formulæ, difficult. It is probable that the branching of the Red-brown section is more complicated than that in the Green section, but this does not show up very clearly for the reasons given. The rate of cane formation is very much more rapid in the Red-brown section.

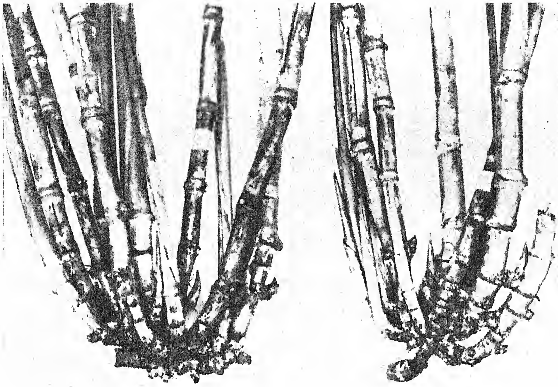
The arrangement of the canes in the clump is characterized by irregularity, canes being produced at all angles, with the outer ones often spreading widely or even prostrate. An intricate mass is thus formed, and, as the attachments are very thin and brittle, dissection, especially in the Red-brown section, is very difficult. There are, in most of the varieties, a large number of runners and the spacing of the canes in the clump is due rather to their irregular arrangement and the presence of these runners than to orderly curving of the outer branches, in this character resembling *Saccharum spontaneum*. The canes are long-jointed, knotted and zigzag, and vary little in thickness in different parts of their length, and there is less ovalness than in most other groups[2] (Pls. XX and XXI).

The appended tables give the varietal formulæ, and the average length of basal parts, length of joints in the lower two feet and thickness at two feet from the base. There is, generally, a marked difference between the branches of different orders. Owing to the comparative absence of curvature in the younger branches, the length of the basal part of the cane does not increase rapidly from *b* onwards.

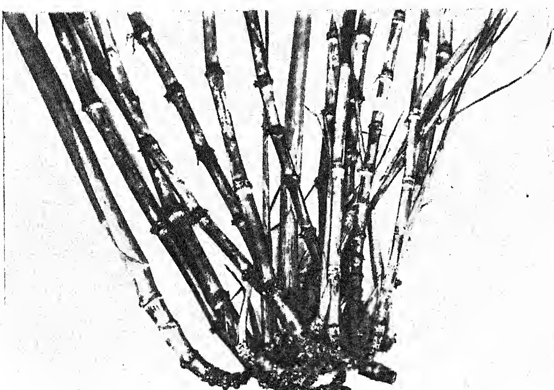
[1] There appear to be several cane varieties included under this name, as in *Baraukha*, *Ketari*, *Chynia*, etc. One *Khari* in our collection is fairly obviously a Pansahi cane.

[2] For fuller descriptions of some varieties in this group, *see* Mem. I, where the primitive Punjab forms are described, and Mem. III, where the general characters of the group and its sections are given in some detail.

SARETHA GROUP.



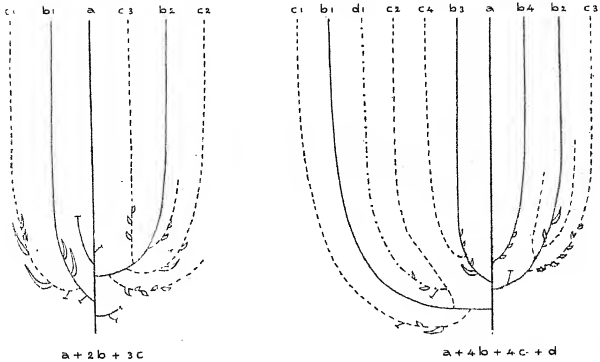
Hullu Kabbu 1916 ($8\frac{1}{2}$ months old). One clump with two plants.



Katha 1916 ($8\frac{1}{2}$ months old). One of three plants in one clump.

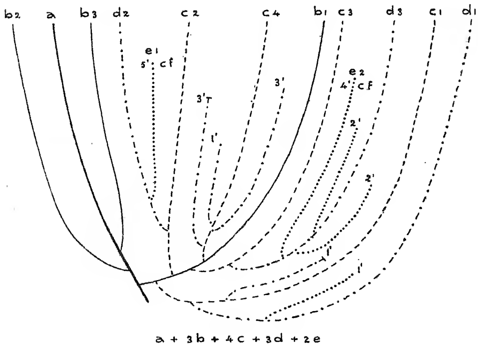
Hullu Kabbu 1916 (8½ months old)

One clump with two plants



Katha 1916 (8½ months old)

One plant out of three in a clump



Diagrams of the branching in the three plants photographed in the previous plate.

FORMULÆ AND MEASUREMENTS IN THE SARETHA GROUP.

1. *Formulæ of canes, shoots, buds, deaths and runners.*

Variety	Number dissected		Canes at harvest							Green shoots					Bursting buds					Dead						Grand Total	Runners
	Clumps	Plants	*a*	*b*	*c*	*d*	*e*	*f*	Total	*b*	*c*	*d*	*e*	*f*	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*		
Chin ...	3	7	0·9	3·0	2·4	1·4	0·1	...	7·9	0·3	2·1	1·6	0·4	0·6	0·1	2·4	3·9	1·0	...	0·1	2·9	3·4	2·6	1·0	...	30·3	0·4
Katha ...	3	9	0·9	3·1	4·3	2·0	0·3	...	10·7	0·4	1·6	1·6	0·6	...	0·7	2·2	3·3	0·3	0·4	0·1	1·1	3·6	1·8	0·9	...	29·3	1·5
Saretha	5	14	0·6	3·2	3·6	0·6	...	...	8·1	0·4	3·5	1·4	0·2	...	0·7	6·1	2·9	1·6	...	0·4	1·9	6·3	1·6	0·1	...	35·2	1·0
Ganda Cheni ..	3	7	1·0	3·1	3·4	0·9	0·1	0·1	8·6	0·3	1·6	1·1	.	...	0·4	5·0	5·9	2·0	0·3	...	2·0	5·6	5·0	1·3	0·6	39·7	1·2
Hullu Kabbu ...	3	8	0·7	3·5	3·2	1·6	0·4	...	9·5	0·2	1·6	1·0	0·5	...	0·2	4·2	5·0	0·2	...	0·2	1·1	3·0	2·5	0·1	...	29·3	0·2
Khari ...	3	8	0·9	3·1	3·6	0·4	...	...	8·0	...	1·9	1·6	...	...	0·4	4·1	7·6	1·2	..	0·1	4·0	7·5	4·9	0·4	...	41·7	0·4
Average	...	...	0·7	3·2	3·4	1·1	0·1	...	8 8	0·3	2·2	1·4	0·3	0·1	0·5	4·2	4·5	1·1	0·1	0·2	2·1	5·0	2·9	0·6	0·1	34·3	

Group formulæ Canes at harvest 1 : 3 : 3 : 1 The whole branching system 1 : 6 : 15 : 10 : 2 Runners 1

2. *Length of basal part, and length and thickness of joints, in branches of different orders.*

Variety	Average length of basal part, in inches						Average length of joints in the first two feet: Number of canes measured					Average length of joints in the first two feet: Average length, in inches					Average thickness of canes at two feet from base: Number of canes measured					Average thickness of canes at two feet from base: Average thickness, in mm.				
	a	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*
Chin	3·3	1·8	2·3	3·0	2·7	...	4	12	6	2	1	2·0	2·5	2·9	2·9	2·5	5	11	6	2	1	124	132	140	152	157
Katha	3·8	2·2	2·0	1·4	...	...	5	19	12	...	...	2·2	2·6	3·0	...	...	5	19	10	...	...	136	135	140	...	...
Saretha	2·8	1·9	2·5	1·7	...	...	7	31	19	6	...	2·5	3·2	3·3	3·2	...	7	35	19	5	...	160	167	174	181	...
Ganda Cheni ...	3·2	2·0	1·8	2·2	1·5	1·5	5	17	15	5	1	2·2	3·0	3·0	3·6	3·5	5	16	12	5	1	197	200	222	225	252
Hullu Kabbu .	2·5	1·8	2·5	1·9	2·7	...	4	12	14	6	.	2·0	3·0	3·9	3·9	..	3	12	11	2	...	175	185	203	207	...
Khari	3·3	2·1	1·7	5·0	..	...	4	18	11	1	...	1·8	2·7	3·5	3·9	...	4	16	7	1	..	162	175	187	193	...
Average ...	3·1	2·0	2·1	2·5	2·3	1·5	...	...		...	...	2·1	2·8	3·3	3·5	3·0	..	...	...	...	...	159	166	178	192	204

Pansahi Group.

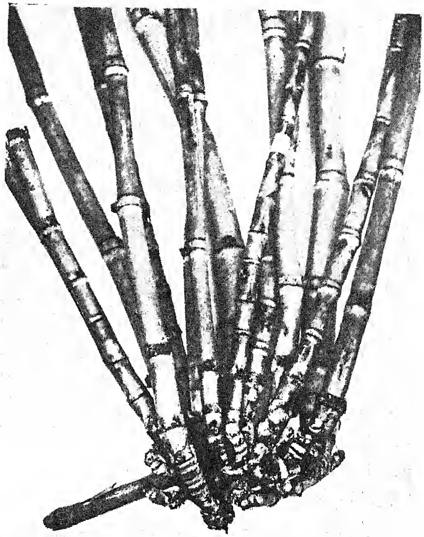
The Pansahi group is very homogeneous, and no subdivisions have as yet been observed in it. The geographical range is fairly wide, but only in an east and west direction. No examples have as yet been received from the Peninsula area, although members of the group have been met with in every province from the Punjab to Burma. The greatest development of the group is perhaps in Bihar, but *Kahu* is found in the Punjab and *Thin Moulmein* in Burma. The group is of especial interest in that it contains *ganna* canes, that is, those intermediate between the thin, hardy *ukh* canes and the *paunda* or thick chewing class; also that it includes the *Yuba*, which is the chief variety grown in Natal. This cane is of special interest in that it appears to have reached Natal from Brazil where it is regarded as a "country" cane.[1] It is quite conceivable therefore that it is the cane taken from the Punjab by Alexander the Great in 326 B. C.[2]

Cane formation takes place early, and the varieties all grow well at Coimbatore; they are very free growing and appear to be little inconvenienced by the rather tenacious, saltish land. In habit, they are regularly cup-shaped, and the leaves fall in a wide curve all round the centre. In branching, they are often very symmetrical (*cf.* fig. 1, p. 157, Mem. III), the inner canes being straight, and the succeeding ones more or less curved according to their distance from the centre; strong curves are found in the later canes, and runners are not uncommon. The attachments are very firm and thick, making it possible to dissect great portions at a time without separating the branches. In many respects the branching system strikingly reminds one of that of *Saccharum arundinaceum*, although there is no trace of connection with that wild form in the other morphological characters. The canes are fairly straight but the joints, especially in the later canes, are long and markedly zigzag, and the nodes are prominent.[3] The Plate following illustrates the general form in *Maneria* and *Pansahi*, but the diagrams of these are not given, as that in Memoir III, referred to above, will suffice. On the other hand, diagrams are given of *Yuba*, and a remarkably well grown plant of this variety is included. (Pls. XXII and XXIII.)

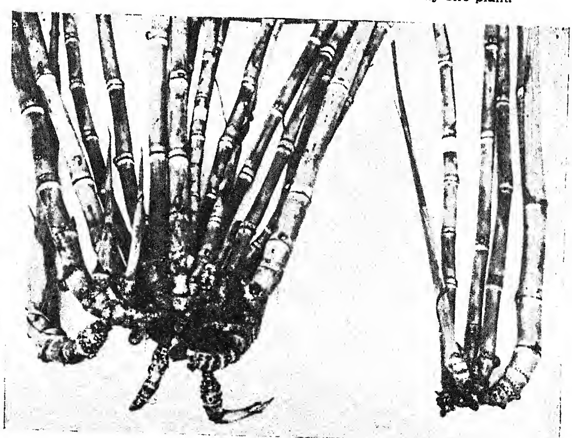
The length of joint shows great regularity in its increase in the branches of successive orders, and the length of the basal part bears evidence of the strong curvature in the later branches. In thickness, the *a*s and the *b*s are practically equal and differ widely from the *c*s and *d*s, thus dividing the canes of the clump into early and late formed canes, which separation is very characteristic of the group. These points are well brought out in the appended table.

[1] Deerr, Noel. The Origin of the Uba Cane. *International Sugar Journal*, April, 1918, p. 164.
[2] C. A. Barber. The Origin of the Uba Cane. *International Sugar Journal*, September, 1918, p. 706.
[3] For fuller description of a cane of this group, *see* Mem. I, pp. 95–103 and Plates XV, XVI and XIX.

PANSAHI GROUP.



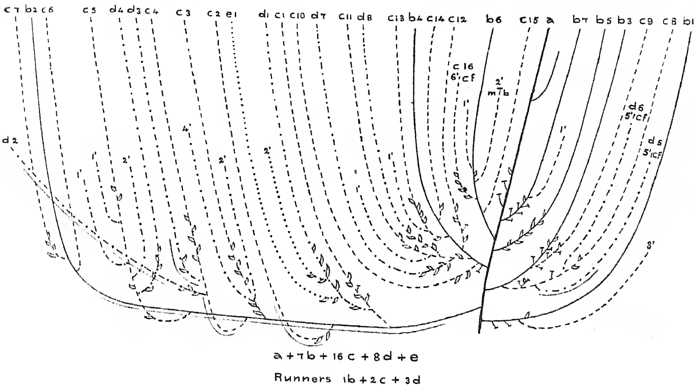
Maneria 1916 (9 months old). A clump with only one plant.



Pansahi 1916 (9 months old).
Two of three plants in one clump: the remaining plant is shown on

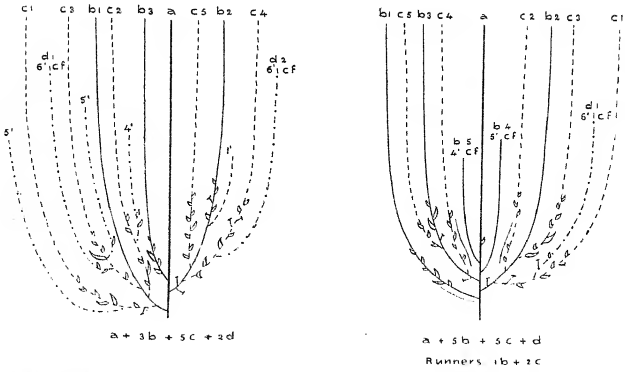
Yuba 1916 (7½ months old)

One clump with two plants. Only the larger plant is drawn.



Yuba 1916 (7½ months old)

One clump with two plants



Diagrams of three *Yuba* plants. The upper diagram is that of an abnormally luxuriant plant, the lower diagrams being more like the normal. A Pansahi diagram is given on p. 157 of Memoir No. III.

FORMULÆ AND MEASUREMENTS IN THE PANSAHI GROUP.

1. *Formulæ of canes, shoots, buds, deaths and runners.*

Variety	Number dissected		Canes at harvest						Green shoots				Bursting buds					Deaths					Grand Total	Runners
	Clumps	Plants	*a*	*b*	*c*	*d*	*e*	Total	*b*	*c*	*d*	*e*	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*		
Chynia	2	2	0·5	4·5	5·5	4·0	...	14·5	...	0·5	2·0	1·5	...	6·5	14·5	20·0	.	0·5	1·0	2·5	6·0	1·0	70·5	1·0
Kahu	2	5	0·6	3·0	3·0	1·8	0·4	9·2	...	0·2	1·6	0·4	1·4	4·6	2·5	3·0	...	0·4	2·4	3·2	1·2	0·2	30·3	1·4
Maneria	3	7	0·9	3·4	3·3	1·9	..	9·4	0·1	1·0	0·6	...	1·0	2·9	3·7	0·6	...	0·1	2·1	5·0	3·1	0·3	29·9	2·2
Pansahi	3	8	1·0	1·9	3·9	1·4	0·5	8·5	0·1	0·5	0·4	0·2	0·4	2·2	5·4	2·4	..	...	1·6	2·9	2·0	0·9	27·5	0·2
Sada Khajee ..	2	3	0·7	3·0	3·7	5·0	..	12·0	...	1·3	0·7	1·0	...	3·0	6·3	14·7	...	0·3	1·0	3·3	1·3	0·7	45·6	2·7
Yuba	2	4	1·0	4·5	6·7	2·7	0·2	15 2	0·2	1·5	2·7	0·2	0·7	10·7	25·0	10·2	1·2	...	0·7	4·5	3·2	0·5	76·5	2·2
Average ...	...	...	0·8	3·4	4·3	3·1	0·2	11·5	0·1	0·8	1·3	0·5	0·7	5·0	9·5	8·5	0·2	0·2	1·5	3·6	2·8	0·6	46·7	1·6

Group formulæ Canes at harvest 1 : 3 : 4 : 3 The whole branching system 1 : 6 : 14 : 17 : 7 Runners 2

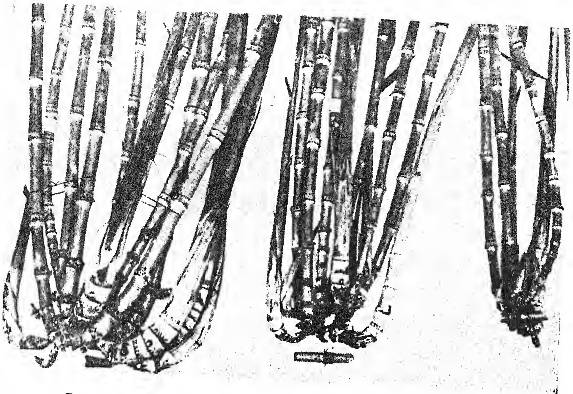
2. *Length of basal part, and length and thickness of joints, in branches of different orders.*

Variety	Average length of basal part, in inches					Average length of joints in the first two feet: Number of canes measured				Average length of joints in the first two feet: Average length, in inches				Average thickness of canes at two feet from base: Number of canes measured					Average thickness of canes at two feet from base: Average thickness, in mm.				
	a	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*
Chynia	4·0	1·7	2·0	2·5	...	1	8	10	6	2·0	2·8	3·3	3·9	1	8	10	6	...	170	163	178	206	...
Kahu	3·7	1·3	1·9	2·7	2·0	3	13	10	7	2·3	2·9	3·2	4·2	3	13	11	7	...	158	159	184	220	...
Maneria	2·9	2·1	1·9	2·8	...	5	18	10	2	1·9	2·8	3·1	4·2	6	23	17	4	...	168	185	216	269	...
Pansahi	3·2	1·6	2·3	2·5	...	5	8	13	1	2·1	3·1	4·8	5·4	8	17	19	13	...	164	164	207	219	...
Sada Khajee	3·3	2·1	2·1	1·8	...	2	7	11	12	2·3	2·9	3·5	4·6	2	8	11	7	...	173	152	177	215	...
Yuba	3·3	1·7	2·1	1·9	2·0	4	15	21	4	2·5	2·9	3·6	4·0	4	15	18	4	1	166	171	174	212	284
Average	3·4	1·7	2·0	2·4	2·0	...	...	...	...	2·2	2·9	3·6	4·4	...	...	...	...	...	166	166	189	223	284

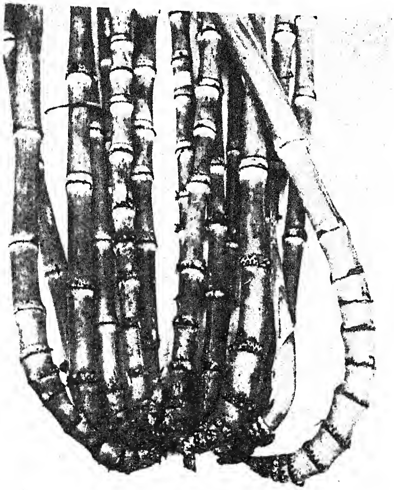
Nargori Group.

The Nargori group is a very distinct one, being readily separated, among other things, by its curious palm-like habit, a bundle of erect, knotted canes surmounted by a thick bunch of short, broadish leaves, often with a brownish or copper coloured tinge in North India. The group appears to be a primitive one. Its distribution along the foot of the Himalayas is apparently less wide than that of the Pansahi group, as specimens have only been received from Bihar and the United Provinces, but varieties belonging to it have also been received from the south of the Central Provinces, and thus it enters the Peninsula. The varieties collected grow fairly well on the Cane-breeding Station. The canes curve very sharply at the base and quickly assume a vertical direction, and the clump thus takes up little room. The branching is not extended, as can be seen from the formula, and there is a marked absence of runners or irregularities of any kind. The canes are very straight, mostly thin, with well marked bloom bands and always strongly noded. The varieties mature early and there are few shoots or bursting buds at nine months from planting, making the preparation of the cane formula easy. The basal portion of the stem is long, especially in the *as*, where there are a large number of short joints under 1″ in length. The average length of joints increases at first slowly and then rapidly with successive branchings, but there is little difference in thickness between the *as* and the *bs*. This makes it an easy matter to separate the early and late formed canes at harvest, as represented by *as*+*bs* and *cs*+*ds* respectively. In two varieties measured, it would seem that the *as* are actually thicker than the *bs* and the figures are equal in a third variety. (Pls. XXIV and XXV.)

NARGORI GROUP.



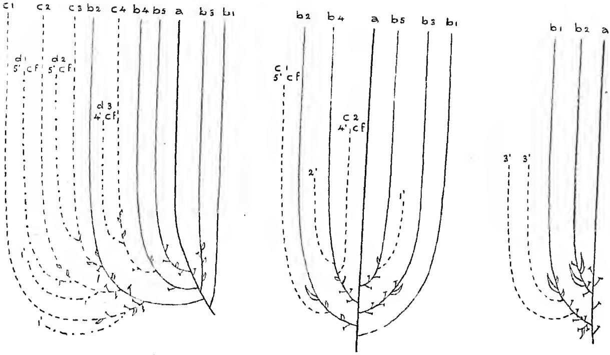
Sararoo 1916 (9 months old). One clump with three plants.



Kewali 1916 (9 months old). Clump with only one plant.

Sararoo 1916 (9 months old)

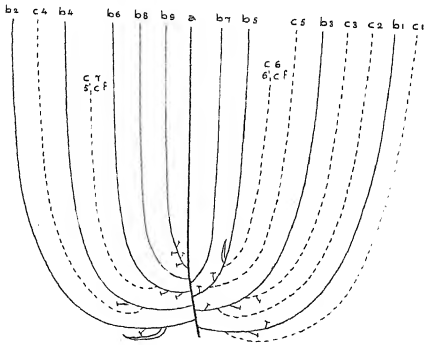
One clump with three plants



a + 5b + 4c + 3d   a + 5b + 2c   a + 2b

Kewali 1916 (9 months old)

One clump with only one plant



a + 9b + 7c

The diagrams of branching of the four plants in the preceding plate.

FORMULÆ AND MEASUREMENTS IN THE NARGORI GROUP.

1. *Formulæ of canes, shoots, buds, deaths and runners.*

Variety	Number dissected		Canes at harvest					Green shoots			Bursting buds				Deaths				Grand Total	Runners
	Clumps	Plants	*a*	*b*	*c*	*d*	Total	*b*	*c*	*d*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*		
Baraukha	2	4	0·7	2·5	2·7	..	6·0	...	0·2	.	0·7	6·0	0·2	...	0·3	1·7	2·0	...	17·1	0·2
Katai	2	6	1·0	3·4	2·8	...	5·2	...	0·4	...	0·4	4·0	0·4	...	...	2·4	4·6	...	17·4	0·3
Kewali	3	6	0·7	4·0	2·7	...	7·5	0·3	0·3	...	0·3	4·2	0·3	...	0·4	1·0	3·5	0·2	19·2	0·0
Nargori	3	7	0·7	2·6	4·1	1·1	8·6	...	1·5	0·3	...	0·7	1·7	0·1	0·3	2·0	8·9	3·9	26·8	0·0
Newra	2	5	0·8	2·0	5·2	...	8·0	...	...	..	0·6	1·4	4·8	..	0·2	1·6	0·4	...	17·0	0·0
Sararoo	3	6	0·8	4·0	3·2	0·7	8·7	...	1·5	0·7	.	4·0	5·3	0·2	0·2	1·3	6·2	2·5	30·6	0·0
Average ...	...	...	0·8	3·1	3·5	0·3	7·8	...	0·6	0·2	0·3	3·4	2·1	...	0·2	1·7	4·3	1·1	21·3	0·1

Group formulæ Canes at harvest 1 : 3 : 3 The whole branching system 1 : 5 : 12 : 4 Runners 0

2. *Length of basal part, and length and thickness of joints, in branches of different orders.*

Variety	Average length of basal part, in inches				Average length of joints in the first two feet								Average thickness of canes at two feet from base							
					Number of canes measured				Average length, in inches				Number of canes measured				Average thickness, in mm.			
	a	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*
Baraukha ...	4·4	1·9	2·3	...	3	10	6		1·8	2·6	3·4	...	3	7	2	...	166	162	173	...
Katai	3·2	1·8	2·6	...	5	17	3	...	2·5	3·5	4·3	...	5	17	13	...	173	163	172	...
Kewali	6·3	2·2	2·3	.	3	14	3		1·5	2·3	3·7	...	3	14	5	...	168	168	181	
Nargori	5·2	2·9	2·2	2·1	2	9	18	1	2·0	1·9	3·1	3·5	5	16	12	4	129	143	171	209
Newra	3·3	1·6	2·3	...	4	9	22	...	2·2	2·6	4·2	...	4	9	8	...	138	159	170	...
Sararoo	5·6	2·1	2·2	...	2	12	10		1·9	2·2	3·7	...	5	22	12	1	135	138	181	218
Average ...	4·7	2·1	2·3	2·1	...	...	...	...	2·0	2·5	3·6	3·5	...	...	...	...	151	156	175	213

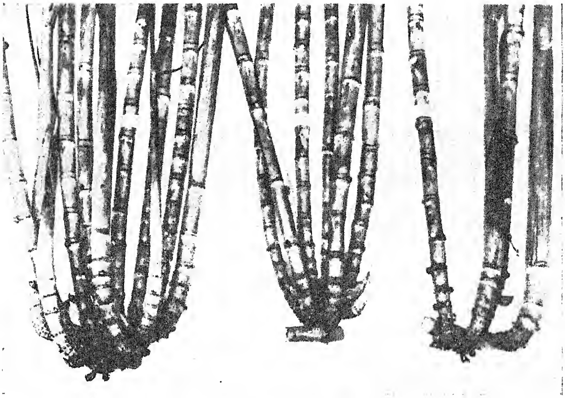
XVI.

Sunnabile Group.

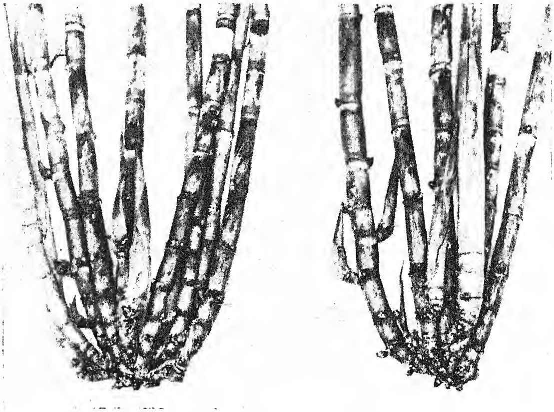
The Sunnabile group, although widely distributed over India, from the Punjab to Assam and Madras, and including canes of all degrees of thickness, is far more homogeneous than the Saretha, as has been fully discussed in Mem. III. But here, too, the geographical distribution appears to have left its mark on the branching system. *Bansa* from Western Bengal appears to be a more vigorous variety than the rest, and *Dhaulu* from the Punjab and *Mojorah* in Assam are also heavier tillerers than the other three examined. These latter are, as pointed out on page 111, Peninsula forms, *Dhor* from the Central Provinces, *Sunnabile* from Bombay and *Naanal* from Madras. Nevertheless, the group, as a whole, is marked by rather sparse branching and a restricted formula, resembling Nargori and approaching the Thick cane group in this respect. The clumps are close and upright and the leaf tips are usually erect. Runners are absent and there are usually many large, white, clawed buds in the dissections. Curving is moderate and merely such as is necessary to bring the canes quickly into parallelism. The canes are soft and often white in colour. The plants are much affected by mealy bug on the farm, possibly due to the slowness of growth and softness of the rind. The general appearance of the dissected clump is one of smoothness and regularity, as can be seen in the photographs, the canes being straight and regular and without any prominent nodes, in these respects resembling varieties of the Mungo group. There is less difference than usual in the canes of different orders in all respects and it would be difficult to separate the early and late canes at harvest.[1] (Pls. XXVI and XXVII.)

[1] For fuller details regarding the characters of this group, *see* Mem. III, where the connecting characters are tabulated and contrasted with those of the Saretha series.

SUNNABILE GROUP.



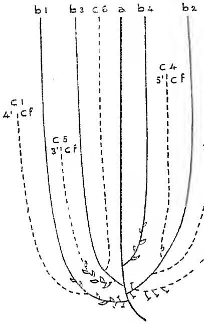
Naanal 1916 (9 months old). One clump with three plants.



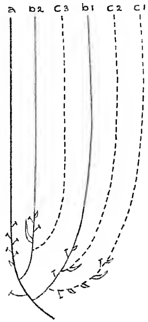
Sunnabile 1916 (9 months old). One clump with two plants.

Naanal 1916 (9 months old)

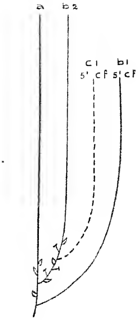
One clump with three plants



a + 4b + 6c



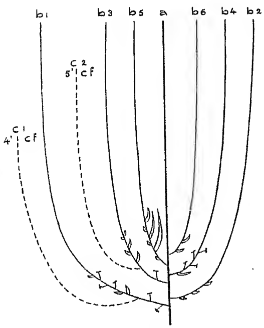
a + 2b + 3c



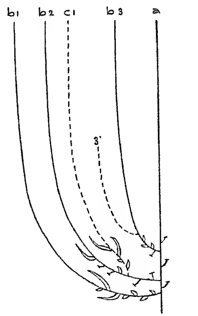
a + 2b + c

Sunnabile 1916 (9 months old)

One clump with two plants



a + 6b + 2c



a + 3b + c

Diagrams of the branching of the five plants in the preceding plate.

Formulæ and measurements in the Sunnabile group.

1. *Formulæ of canes, shoots, buds, deaths and runners.*

Variety	Number dissected		Canes at harvest					Green shoots			Bursting buds				Deaths					Grand Total	Runners
	Clumps	Plants	a	b	c	d	Total	b	c	d	b	c	d	e	a	b	c	d	e		
Bansa	3	6	1·0	5·2	3·0	0·8	10·0	0·2	0·8	0·8	0·5	4·7	2·5	0·7	...	2·8	17·2	3·7	0·2	44·1	0·8
Dhaulu	3	10	1·0	2·4	2·2	0·1	5·7	0·1	0·1	0·1	1·7	4·7	2·3	...	...	3·7	6·4	1·9	...	26·7	0·3
Dhor	3	8	1·0	2·0	1·9	...	4·9	2·5	0·5	0·1	0·4	4·6	7·2	...	...	4·7	4·7	1·2	...	30·8	0·0
Mojorah	2	6	1·0	4·0	1·0	.	6·0	0·2	0·3	...	0·7	7·8	0·8	...	...	5·0	14·8	0·8	...	36·4	0·3
Naanal	3	8	1·0	2·4	1·6	...	5·0	...	1·0	...	1·4	7·7	3·4	...	...	4·6	5·7	1·4	...	30·2	0·2
Sunnabile	3	8	0·9	2·7	2·5	...	6·1	...	2·2	0·7	0·9	9·1	5·7	0·4	0·1	2·4	5·2	0·9		33·7	0·7
Average	...	...	1·0	3·1	2·0	0·1	6·3	0·6	0·8	0·3	0·9	6·4	3·6	0·2	..	3·9	9·0	1·6	...	33·6	0·4

Group formulæ Canes at harvest 1 : 3 : 2 The whole branching system 1 : 8 : 16 : 6 Runners 0

2. *Length of basal part, and length and thickness of joints, in branches of different orders.*

Variety	Average length of basal part, in inches				Average length of joints in the first two feet								Average thickness of canes at two feet from base							
					Number of canes measured				Average length, in inches				Number of canes measured				Average thickness, in mm.			
	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d	a	b	c	d
Bansa	2·2	1·5	2·2	2·2	5	25	12	1	1·8	2·5	3·0	2·6	6	27	9	...	169	155	178	...
Dhaulu	2·9	2·3	3·2	3·5	10	24	21	...	2·2	2·5	3·1	...	10	22	13	...	173	151	159	..
Dhor	3·2	2·5	4·6	..	4	5	7	..	1·6	2·1	2·4	...	8	17	9	...	187	200	241	...
Mojorah... ...	2·5	2·2	2·0	...	6	23	4		1·9	2·7	2·8	...	6	21	1	...	237	237	240	...
Naanal	3·2	2·4	4·5	...	5	12	7	..	2·0	2·1	3·4	...	8	18	6	..	207	203	211	
Sunnabile ...	2·0	1·5	2·5	2·0	5	12	9	1	1·8	2·2	3·0	2·5	7	21	14	1	192	205	227	262
Average ..	2·7	2·1	3·2	2·6	...	...	...	..	1·9	2·3	2·9	2·5	...	...	..	...	189	192	209	262

Mungo Group.

The Mungo group can at once be separated from the other indigenous canes of India by the dwarf, bushy habit of its members. This varies, it is true, in the group itself and with the locality. *Kuswar*, for instance, sometimes grows to quite a respectable height, as at Shahjahanpur and at Pusa, while it is as short as the others at Coimbatore; it is therefore somewhat difficult to draw the line, from the habit alone, between the Mungo varieties and the taller transitional forms, *Bodi*, *Sanachi* and possibly *Dhaulu of Phillaur* which have been placed in the unclassified list. But, in comparison with some others, the group is remarkably homogeneous. In the six varieties selected at haphazard for dissection, *Kharwi* shows itself to be somewhat different, in its branching and especially in the rate of cane-formation, from the rest, and *Katara* is between *Kharwi* and the others in the latter respect. But, as a whole, the group is markedly late in maturing. It must however be especially emphasized that the diagrams of canes at harvest are not altogether comparable among the varieties themselves nor with those of other groups, and for the following reasons. The shortness of the joints often causes there to be a large number of buds on the set, and a correspondingly large number of individual plants in the clump, with a consequent abbreviation of the plant formulæ. Thus, *Hemja* has fifteen plants in the three clumps, *Rheora* fourteen in three clumps, *Katara* fourteen in four clumps, *Mungo* and *Kuswar* ten in three clumps, while *Kharwi* has only four plants in two clumps. In *Hemja* two clumps have seventeen plants between them (Plate XVI), while in *Kuswar* there is one clump with only a single plant growing (Plate XXVIII). Taking these facts into consideration, the typical plant formula of canes at harvest in this group is a very extended one, being, even as it is, on a par with those of the Saretha and Pansahi groups.

In habit, the Mungo varieties assume the form of a low bush, with very short, thickish canes, and a uniform mass of drooping leaves all round. The canes are white in the Cane-breeding Station, but in North India often assume delicate rosy tints. The form of the dissected mass of canes is a rounded cup or bowl (Plate XXVIII), and the individual canes are straight or slightly curved, uniform, short-jointed and without prominent nodes, in these respects somewhat reminding one of abbreviated Sunnabile canes. The limits of the growth rings are usually very indefinite, there is a strongly marked, thin scar line, and the buds have blackened flanges. The leaves are rather narrow and the leaf sheaths long. These characters, together with the habit, make the group a very distinct one, and it is difficult to obtain connecting links between

it and the other indigenous groups, except perhaps through the *Bodi, Sanachi* and *Dhaulu of Phillaur* canes, with the Sunnabile series. Runners are not uncommon, and may be horizontal, ascending or vertical, according to need. In spite of the congested nature of the clump, curvature is not very strong, which fact we see reflected in the average length of the basal part of the cane in branches of higher orders, where it seldom reaches that in the main shoot. Variations in thickness and length of joint are also not great, which makes it difficult to separate the early and late canes at harvest. (Pls. XXVIII–XXX.)

FORMULÆ AND MEASUREMENTS IN THE MUNGO GROUP.

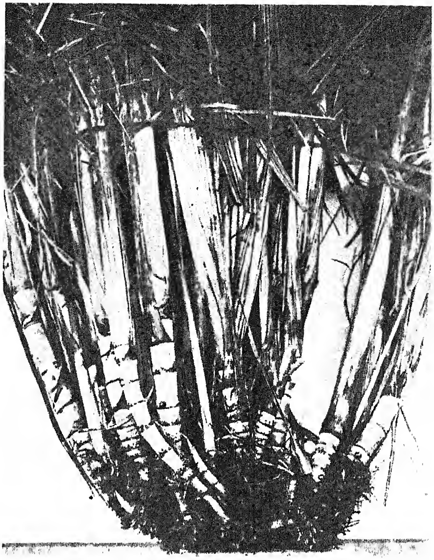
1. *Formulæ of canes, shoots, buds, deaths and runners.*

Variety	Number dissected		Canes at harvest						Green shoots				Bursting buds				Deaths					Grand Total	Runners
	Clumps	Plants	*a*	*b*	*c*	*d*	*e*	Total	*b*	*c*	*d*	*e*	*b*	*c*	*d*	*e*	*a*	*b*	*c*	*d*	*e*		
Hemja	3	15	0·9	1·9	1·5	0·1	...	4·3	0·5	0·9	0·3	...	2·5	4·8	2·9	.	0·1	2·7	5·7	2·3	...	27·0	0·6
Katara	4	16	0·7	2·8	2·1	0·6	0·1	6·3	...	0·9	0·2	...	2·3	10·2	6·2	1·0	0·3	2·5	7·4	2·7	0·8	40·8	0·0
Kharwi	2	4	0·7	5·0	7·7	5·0	0·2	18·6	...	1·5	0·2	...	1·7	11·7	23·0	9·7	0·3	2·7	9·0	7·7	3·7	89·8	2·0
Kuswar	3	10	0·3	2·2	3·2	3·3	0·6	9·6	...	0·6	0·7	0·4	0·6	6·8	7·3	7·3	0·7	1·4	4·8	4·6	2·9	47·7	0·7
Mungo	3	10	0·7	3·3	3·0	1·2	...	8·2	...	1·2	0·9	0·5	1·0	7·6	5·8	1·7	0·3	3·7	8·6	7·3	1·4	48·2	1·7
Rheora	3	14	0·9	2·2	1·6	0·1	...	4·8	0·1	0·3	0·1	...	2·0	6·9	4·5	...	0·1	2·0	4·2	1·9	.	26·9	0·2
Average of varieties ...			0·7	2·9	3·2	1·7	0·1	8·6	0·1	...	...	...	...	...	...		...	...	...	...	...	46·8	1·0

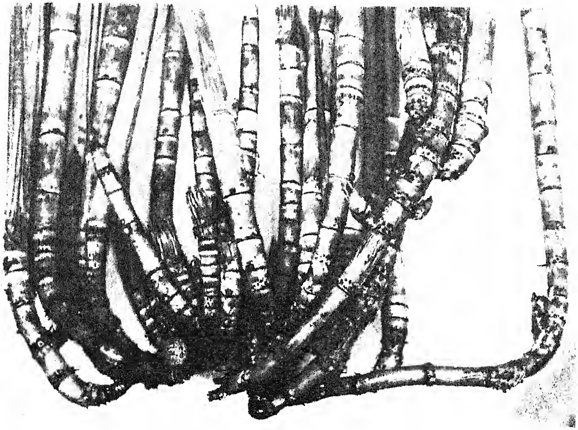
Group formulæ Canes at harvest 1 : 3 : 3 : 2 The whole branching system 1 : 7 : 18 : 14 : 5 Runners 1

2. *Length of basal part, and length and thickness of joints, in branches of different orders.*

Variety	Average length of basal part, in inches				Average length of joints in the first two feet: Number of canes measured				Average length of joints in the first two feet: Average length, in inches				Average thickness of canes at two feet from base: Number of canes measured				Average thickness of canes at two feet from base: Average thickness, in mm.			
	a	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*
Hemja	5·6	4·3	4·3	...	8	18	2	...	1·6	1·9	1·3	...	15	27	8	.	213	224	263	...
Katara	4·4	3·3	3·5	4·0	9	32	21	3	1·8	2·0	2·0	2·0	15	48	32	8	210	217	239	219
Kharwi	4·2	3·3	2·8	2·5	3	19	25	12	1·9	2·2	3·1	3·4	3	19	24	14	156	141	148	147
Kuswar	4·7	3·3	3·5	4·5	2	20	24	15	1·8	1·9	1·9	2·5	3	18	27	15	181	197	221	241
Mungo	3·9	3·5	2·6	(4·2)	6	23	18	3	1·7	2·1	2·3	2·1	7	31	25	6	187	184	198	211
Rheora	4·6	5·8	3·4	(2·0)	10	27	12	...	1·7	1·8	2·0	...	13	26	10	...	177	179	193	..
Average of varieties	4·2	3·6	3·7	3·7	...	..	...	...	1·7	2·0	2·1	2·5	...	...	...	..	187	190	210	204

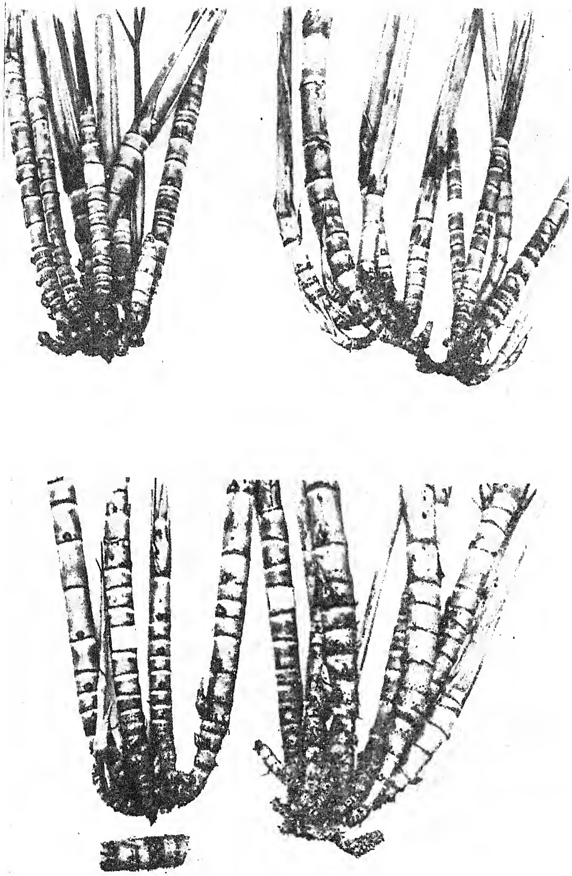


Hemja 1916 (9 months old). Clump before dissection
(*cf.* Plate XXIX and lower diagram on Plate XXX.)



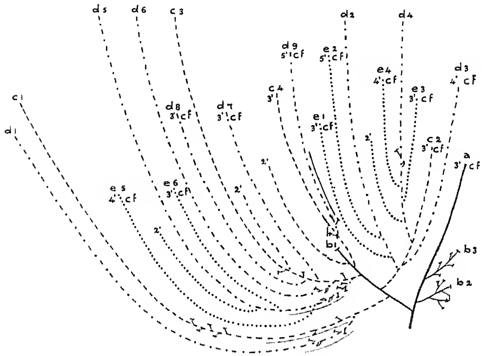
Kuswar 1916 (9 months old). Clump with only one plant

MUNGO GROUP.



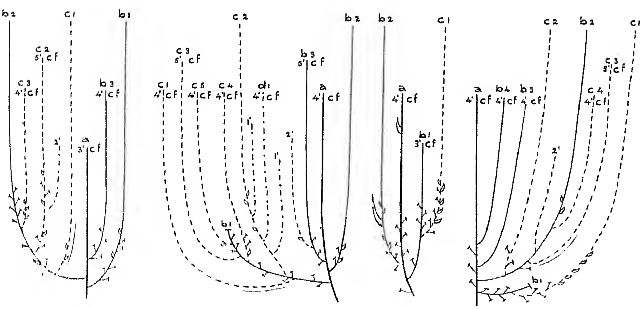
Hemja 1916 (9 months old). Clump on Plate XXVIII dissected (four plants).

Kuswar 1916 (9 months old)
One clump with only one plant



a + 4c + 9d + 6e
Runners 1c + 3d

Hemja 1916 (9 months old)
One clump with four plants



a + 3b + 3c
Runner 1c

a + 2b + 5c + d
Runner 1c

a + 2b + c

a + 3b + 4c
Runner 1c

Diagrams of branching of plants photographed in the two preceding plates.

Thick Cane Group.

This group, as represented in the varieties dissected, is a heterogeneous lot, taken more or less at haphazard. *Java* is a cane received from Mysore and said to have been sent there from Samalkota, but the record is lost. *Red Mauritius* is a somewhat hardy, freely tillering form, extensively grown all over the Peninsula. It was first isolated as a good variety at Samalkota and came to that place from Bombay. Judging by specimens collected in various places in North India, it has probably been in the country for a considerable time, having, as its name implies, its origin in Mauritius. The Louisiana canes were received direct from America. *Vendamukhi* and *Yerra* are apparently thick canes which have been in Bengal and Madras respectively for a long time, probably for centuries, and belong to the doubtful forms elsewhere classed as "half-thick" canes (*cf.* p. 62); there is some doubt as to their ultimate origin and affinities. As pointed out on a previous page, we have not as yet a satisfactory classification of the thick canes. With this varied character in the components of the Thick cane class dissected, it is not surprising that *Red Mauritius* and the Louisiana canes have a somewhat more extended formula than the others, but it is worth noting how little the difference really is. The average formula of canes at harvest is shorter than in any class of Indian canes.

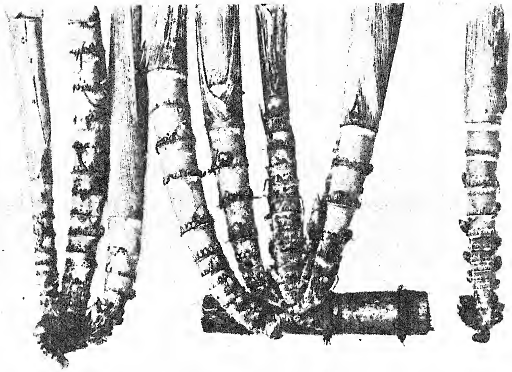
The growth of the thick canes at the Cane-breeding Station is not very satisfactory, as this class of canes requires a much better soil, with more manure and water than the native canes. Cane formation is comparatively early, most likely partly because of the few canes developed per plant. There are a great number of bursting buds as well as of deaths, both in these and in older shoots. In spite of the small number of canes per clump, there is distinct curvature in the latter canes, probably due to the thickness of the canes, but this curvature is not so great as in the Pansahi and other groups. Dissections of *Red Mauritius* canes grown at Nellikuppam have been added separately, and show the possibilities of branching in this cane in well manured, free soil. The group formula at Coimbatore is $1a+2b+1c$, and that at Nellikuppam, for *Red Mauritius* alone $1a+3b+3c+1d$. The basal part of the cane is longest in the *a*s, and decreases somewhat regularly in the branches of higher orders, not being apparently interfered with by the curvature of the latter. The length of joint in the first two feet falls into line with that of the indigenous canes studied, being lowest in the *a*s and increasing in successive orders of branches, and a similar increase is noticeable in the thickness of the canes at two feet from the base.

The Nellikuppam canes agree, generally, in these particulars, but the canes grown on the wet land, instead of increasing in thickness show a steady decrease. This is not at present explained, but must not be lost sight of in drawing conclusions. Separation of early and late canes in the clump should be fairly easy, but we have at present insufficient experience with this class of cane to make generalizations, and further observations are desirable.

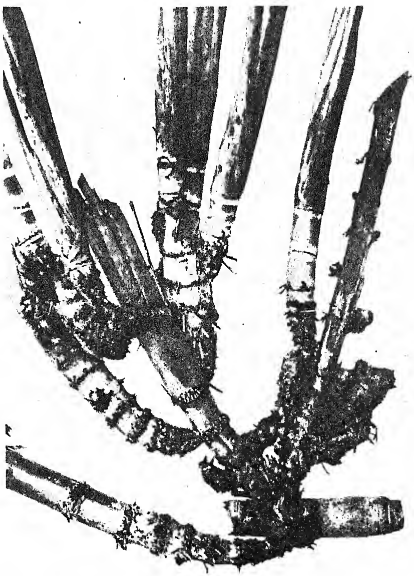
In 1916-17, several clumps of Thick cane ratoons were dissected, and a photograph and some drawings of these are reproduced. During 1917-18 twelve clumps of *Red Mauritius* ratoon canes were dissected at Nellikuppam, half of these being in wet land and half in dry, as was the case with the twelve plant cane clumps examined there. A couple of diagrams of these ratoon dissections are added. The individual canes in these ratoons were treated in exactly the same manner as those of the plant cane clumps. Formulæ and diagrams were constructed, the length of the basal part was measured in each cane, and the average length of the joints in the lowest two feet and the thickness at two feet from the base were recorded. (Pls. XXXI–XXXIII.)

As the original *set* was in all cases still attached, we can thus obtain a very clear idea as to what takes place when a cane crop is cut and the stool allowed to grow on for another year. The analysis shows that the canes in these clumps had an average formula, in the first year, of $a+3b+2c$ per plant, and, in the second, of $1c+3d+1e$. In both of these formulæ we note that the plants in the ratooned series were less well grown than in the plant canes dissected at the same time, where the formula was $a+3b+3c+1d$, and in fact the formula for each year falls into close agreement with that obtained at the Cane-breeding Station. In the diagrams, a convention has been introduced, by which each cane cut in the first year is indicated by a heavy black dot at its end. It is interesting to note that all the buds on the first year's canes have died, excepting such as grew out to form new canes in the second year. Instructive data are given as to the relative growth and ratooning power of the wet and dry land canes, but perhaps it would be better to have a larger series of figures at disposal before drawing any conclusions.

THICK CANE GROUP.



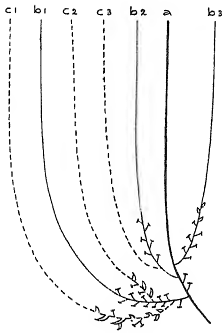
Java 1916 ($5\frac{1}{2}$ months old). Three plants in one clump.



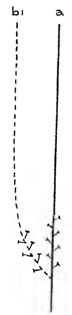
Red Mauritius Ratoon 1916 (*cf.* Plate XXXIII), 20 months old.

Java 1916 (9½ months old)

One clump with two plants



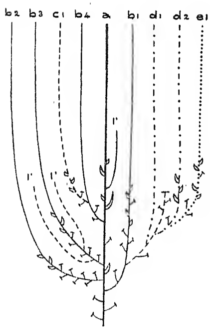
a + 3b + 3c



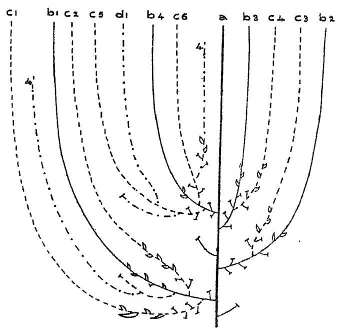
a + b

Red Mauritius, Nellikuppam (12 months old)

One clump with two plants



a + 4b + 1c + 2d + e

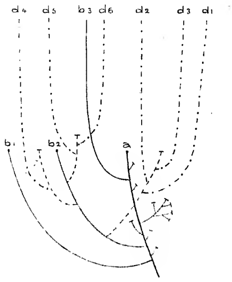


a + 4b + 6c + 1d

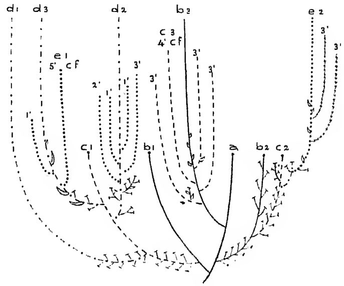
Diagrams of branching in thick canes at Coimbatore and Nellikuppam.

Red Mauritius Ratoons

Two ratoon plants at Coimbatore (20 months old)

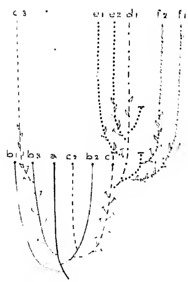


1915 - 16 a + 2 b
1916 - 17 . . b + 6 d
(Photographed on Plate XXXI)

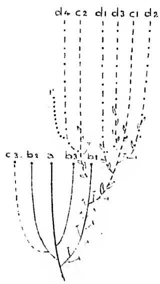


1915 - 16 a + 2 b + 2 c
1916 - 17 . . b + c + 3 d + 2 e

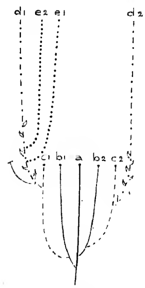
Three plants from one clump. Nellikuppam (25 months old)



1896 - 7 a + 3 b + 2 c
1897 - 8 . . . . c + d + 2 e + 2 f



1896 - 7 a + 3 b + c
1897 - 8 . . . 2 c + 4 d



1896 - 7 a + 2 b + 2 c
1897 - 8 . . . . 2 d + 2 e

Diagrams of the branching of *Red Mauritius* ratooned plants at Coimbatore and Nellikuppam.

Formulæ and measurements in the Thick cane group.

1. *Formulæ of canes, shoots, buds, deaths and runners.*

Variety	Number dissected: Clumps	Number dissected: Plants	Canes at harvest: a	Canes at harvest: b	Canes at harvest: c	Canes at harvest: d	Canes at harvest: Total	Green shoots: b	Green shoots: c	Green shoots: d	Green shoots: e	Bursting buds: b	Bursting buds: c	Bursting buds: d	Bursting buds: e	Deaths: a	Deaths: b	Deaths: c	Deaths: d	Deaths: e	Grand Total	Runners
Java	5	12	0·5	1·3	0·8	...	2·7	...	...	...	...	1·6	4·4	2·7	..	0·5	2·1	3·6	0·7		18·3	0·0
Louisiana purple	3	4	0·7	1·5	2·8	0·8	5·7	...	0·2	0·5	0·2	1·7	3·5	10·2	...	0·2	2·2	2·7	5·5	...	32·6	0·0
Louisiana striped	4	10	0·8	0·9	1·2	0·4	3·1	0·1	0·4	0·1	..	2·8	3·4	5·0	1·0	0·2	2·8	2·2	2·2	0·5	23·8	0·0
Red Mauritius	3	8	0·7	2·6	1·1	0·2	4·7	0·2	1·0	...	...	2·2	9·0	4·1	...	0·2	2·5	6·4	1·7	...	30·0	0·0
Vendamukhi	2	3	1·0	3·0	1·0	...	5·0	0·3	0·3	...	...	2·0	4·0	1·7	...	...	7·0	6·3	2·7	...	29·3	0·3
Yerra	2	4	1·0	2·5	1·2	...	4·7	...	2·0	...	...	1·7	8·0	4·5	..	...	4·5	6·2	3·5	...	35·1	0·0
Average of varieties ...		...	0·8	2·0	1·3	0·2	4·3	0·1	0·6	0·1	...	2·0	5·4	4·7	0·2	0·2	3·5	4·6	2 7	0·1	28·3	0·0

Group formulæ   Canes at harvest 1 : 2 : 1   The whole branching system 1 : 8 : 12 : 8   Runners 0

Red Mauritius, Nellikuppam, Dry land ...	6	16	0·9	3·3	2·8	1·1	8·3	0·1	0·6	0·3	0·2	2·1	10 9	5·0	1·6	0·1	2·1	7·9	3·9	0·8	43·9	...
Red Mauritius, Nellikuppam, Wet land ...	6	15	1·0	2·7	2·3	0·5	6·6	...	0·3	0·7	0·1	1·9	9·2	5·9	0·7	...	1·5	7·4	4·8	0·9	40·0	...

Red Mauritius Ratoons : Formula Canes at harvest 1 : 3 : 1

—	Number dissected: Clumps	Number dissected: Plants	Canes cut 1916-17: a	Canes cut 1916-17: b	Canes cut 1916-17: c	Canes cut 1916-17: d	Canes at harvest 1917-18: c	Canes at harvest 1917-18: d	Canes at harvest 1917-18: e	Canes at harvest 1917-18: f	Canes at harvest 1917-18: g	Canes at harvest 1917-18: Total	Green shoots: d	Green shoots: e	Green shoots: f	Bursting buds: d	Bursting buds: e	Bursting buds: f	Bursting buds: g	Bursting buds: h	Deaths: c	Deaths: d	Deaths: e	Deaths: f	Deaths: g	Grand Total 1917-18	Runners
Dry land ...	6	10	1·0	3·1	1·9	..	1·3	2·5	0·3	0·1	0·1	7·0	0·1	1·8	0·6	4·4	9·0	7·2	2·0	0·1	...	1·3	3·2	1·3	0·9	38·9	0
Wet land ...	6	15	1·0	3·1	2·7	0·1	0·9	2·9	0·7	...	..	4·7	0·2	0·4	0·3	4·1	10·7	2·5	0·1	...	0·1	2·1	4·6	1·1	0·1	31·0	0

FORMULÆ AND MEASUREMENTS IN THE THICK CANE GROUP—*contd.*

2. *Length of basal part, and length and thickness of joints, in branches of different orders.*

Variety	Average length of basal part, in inches				Average length of joints in the first two feet: Number of canes measured				Average length of joints in the first two feet: Average length, in inches				Average thickness of canes at two feet from base: Number of canes measured				Average thickness of canes at two feet from base: Average thickness, in mm.			
	a	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*	*a*	*b*	*c*	*d*
Java ...	3·5	2·8	2·5	...	4	7	2	...	1·8	2·3	3·3	...	6	12	5	...	281	281	324	...
Louisiana purple ..	2·7	4·8	3·2	3·8	2	6	11	4	2·2	2·4	2·7	2·4	2	6	11	3	284	290	299	357
Louisiana striped...	4·6	4·0	4·2	3·5	6	9	12	1	2·3	2·1	2·2	2·7	6	8	11	1	254	265	274	361
Red Mauritius ...	4·7	3·6	2·8	3·0	5	12	7	1	1·9	2·8	3·6	3·8	6	21	9	2	270	312	347	316
Vendamukhi ...	5·0	3·8	3·7	..	3	9	2	...	1·4	2·2	2·3	...	3	9	2	...	264	278	291	...
Yerra	5·5	3·5	3·3	..	4	8	8	...	1·5	2·2	2·8	...	4	8	3	...	226	264	257	
Average ...	4·3	3·7	3·3	3·4	...	...	...	...	1·8	2·3	2·8	3·0	..	...	...	...	263	282	298	345
Red Mauritius, Nellikuppam, Dry land	3·5	2·7	2·5	2·2	15	51	40	16	2·6	3·0	3·4	3·5	15	52	49	7	292	304	305	299
,, Wet land	3·5	2·8	2·5	2·3	15	38	34	7	2·6	3·2	3·3	3·3	15	41	35	8	290	274	266	270

Wild Saccharums.

The wild Saccharums, grown on the Cane-breeding Station for several years, consist of various types of *Saccharum spontaneum*, *Saccharum arundinaceum* and *Saccharum Munja*, and a single form of *Saccharum Narenga*. (Pl. XXXIV.) The two latter have at various times been more or less carefully studied and dissections made of their underground parts, but, as they do not form canes in the ordinary sense, we have been content, in the present Memoir, with reproducing the diagrams of a couple of clumps, from which their bushy, grass-like habit may be inferred. (Pl. XXXVII.) Some idea of their underground parts may be obtained from a study of the Plates in Hole's Memoir referred to above. An interesting series of crosses have been raised between the local thick *Vellai* cane and *Saccharum Narenga*, which will doubtless well repay a detailed study (*cf.* Mem. No. II, Plates IXa to XI).

(1) *Saccharum arundinaceum*, Retz., is a very distinct form. It is typically at home in the moister, eastern portions of the north of India and in parts of Burma, where it occurs wild and flowers freely. Elsewhere, although often planted and then growing well, it rarely flowers. In South India it is constantly planted around the gardens of *betel* pepper, and shows itself well adapted to heavy, water-logged soil. In spite of a diligent search during several years, only isolated cases have been met with where it was in flower, and here the inflorescence was invariably diseased. It has not therefore been possible to obtain crosses with cultivated canes on the farm.

The species is at once recognizable by its mass of tall, thick, cane-like stems, largely covered by the dead leaf sheaths, its broad curving leaves and the large, dense plumes of white or brownish flowers. The canes have fairly long joints and are distinctly noded. These are peculiar in having only one row of root eyes. The leaves are also distinguished by a mass of long brown hairs extending up the base of the lamina on either side of the mid-rib. But these hairs vary in different parts of the plant, and ultimately disappear in the upper leaves, which more resemble those of cultivated canes. These characters of leaf and joint have not been observed in any forms of *Saccharum officinarum*, which closely resembles *Saccharum spontaneum* in these and other respects. There is, of course, also the difference in the hairy vestiture of the flowers, which separates *Saccharum arundinaceum*, and puts *Saccharum spontaneum* and the cultivated canes into the same botanical section.

The branching of *Saccharum arundinaceum* is characterized all through by its symmetrical development. The canes are erect and parallel, often

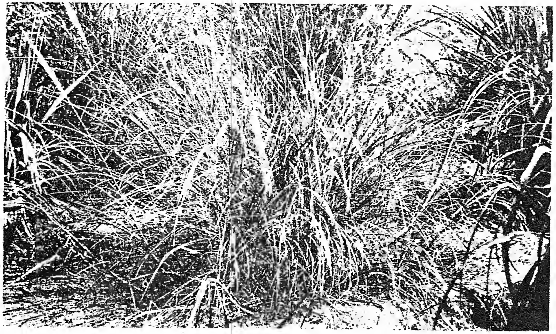
however, bending outwards from the weight of their leafy tufts. There is comparatively little curvature, but the later shoots show this at their very base. The basal curved portion of later formed branches is characterized by its immense thickness, and by being covered by a shaggy coat made up of leaf bases, flat, scale-like buds and dense masses of brown silky hairs. This thickened part of the cane is distinctively dorsi-ventral, and the two rows of buds are thrown on to the outer portion of the curve. There are no runners. The average length of the basal part in the five plants dissected is 2·9″ in *a*, 2·1″ in *b* and 2·4″, 2·9″, 3·2″, in *c*, *d*, *e*, respectively, the small basal curvature thus having its full effect. The average length of the joint in the lowest two feet, and the thickness at two feet from the base, show continuous increases from *a* to the branches of higher orders (*cf.* Pl. I and Table appended).

(2) *Saccharum spontaneum.* Three forms of this species, among those grown at the Cane-breeding Station, have been selected for dissection, namely, the ordinary thin, grass-like form found in waste places in all parts of India, the Dacca pond form, and the Javanese variety called *Glagah.* The latter appears to be more or less intermediate between the two others, and it may be surmised therefrom that the general climate in Java is moister than that of India. There were great variations in the growth of these forms in the dissection plots, but they were all three disappointing, especially at first. This may be caused by a slow early development of the species, but is more likely due to their being unaccustomed to being grown from sets. They are capable, later on, of taking good hold of the cultivated ground, and the Dacca *spontaneum* plants, being very poor at first, formed dense masses of stalks at nine months, when grown from sets, as parents in the seedling plots. This can be readily imagined after an inspection of the diagrams on Plate XXXVI.

In habit, *Saccharum spontaneum* plants grown from seed vary a great deal (*see* Plate XXI, Mem. II), the young seedlings sometimes lying flat on the ground, and at others growing erect and branching sparsely. The general differences in appearance of the Indian varieties here discussed can be seen from an examination of Plates I and II of Mem. III. Differences in thickness are seen to be marked in these Plates. Runners are present in all the forms, those in the Dacca variety extending long distances in the mud, and, in the ordinary land form, appearing above ground at intervals somewhat widely separately from the parent stock. In the plots of seedlings raised from the different forms during the past year on the farm, there were great variations in the width of the leaves, and an analysis showed an equal difference in the sucrose content of the juice. Selections have been made in both these

PLATE XXXIV.

1



2

3

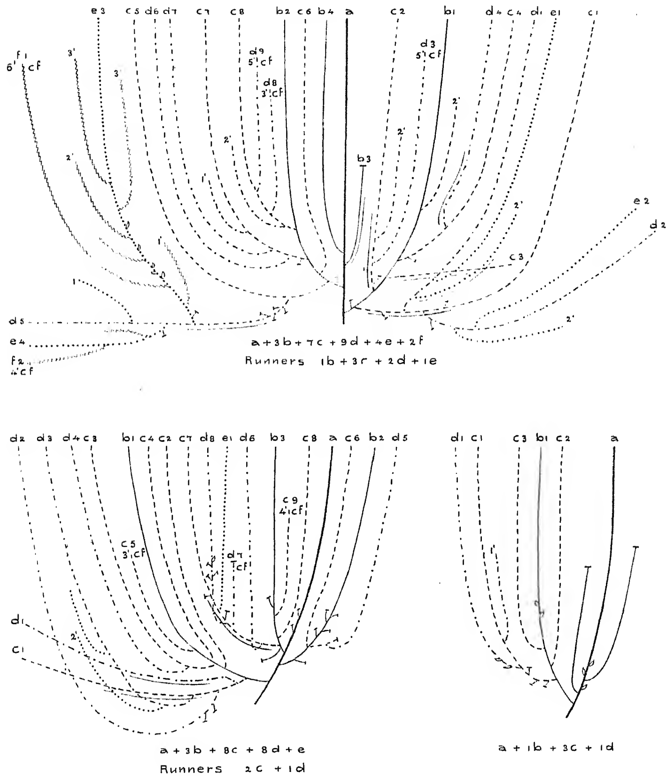
4

Wild Saccharums. Fig. 1, *Saccharum spontaneum*, common Indian form at Coimbatore. Fig. 2, *Saccharum spontaneum*, broad-leafed, water form, in a pond at Dacca. Fig. 3, *Saccharum Munja* at Lyallpur. Fig. 4, *Saccharum arundinaceum* at Lyallpur.

Saccharum spontaneum 1917 (7½ months old)

Local Coimbatore

One clump with three plants

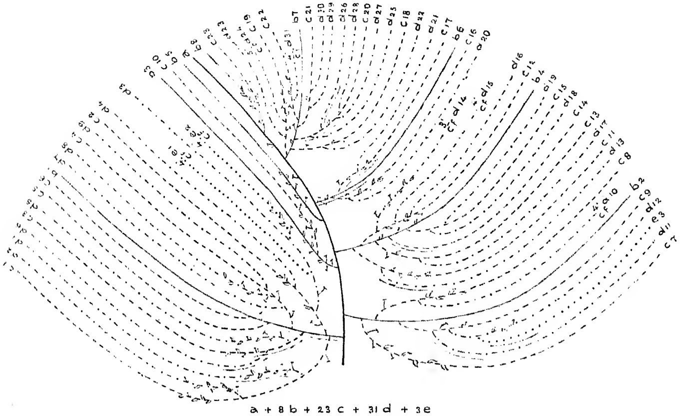


Diagrams of branching of *Saccharum spontaneum*, common Indian form, grown from a set.

Saccharum spontaneum 1917 (10½ months old)

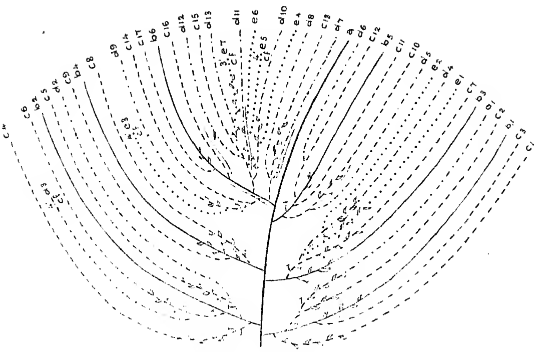
Dacca variety

One clump with two plants



a + 8b + 23c + 31d + 3e

Runners 2b + 4c + 5d + e

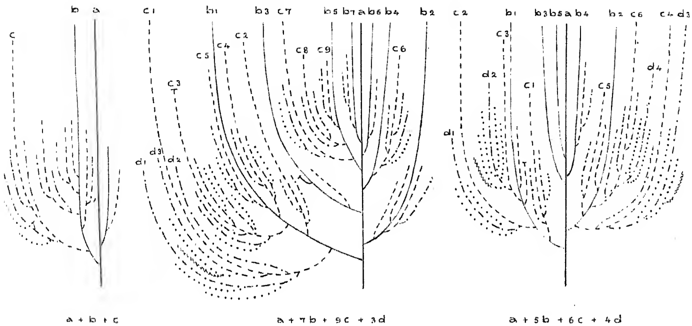


a + 6b + 17c + 13d + 7e

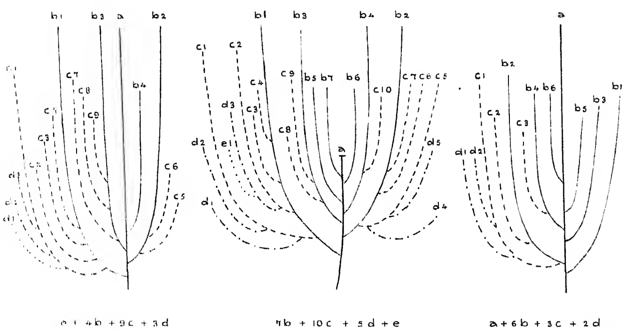
Runners 1b + 2c + 3d

Diagrams of branching of *Saccharum spontaneum,* Dacca pond form. A well grown clump grown, from a set, as parent in the seedling plots at Coimbatore.

Saccharum Munja 1917 (9 months old)
One clump with three plants



Saccharum Narenga 1917 (5 months old)
One clump with three plants



Diagrams of *Saccharum Munja* and *S. Narenga* grown from sets at Coimbatore. The branches with letters affixed had a small piece of hard cane at the base of each. The upper parts of the branches do not form cane.

directions for some years, in order to provide better material for crossing with thick canes. Already two such crosses have been distributed for trial on provincial farms. The cane formulæ obtained by dissecting plants from six to nine months agree fairly well in the three forms, being very extended. The Dacca plant, at first very backward, became extremely luxuriant at nine months and had many more branches than the others, as can be seen from the figures in the Table. In appearance, these Dacca plants are much more like cultivated canes than the other two varieties. The average length of the basal portions, the average length of joint for the first two feet, and the thickness at two feet from the base, show the regular variations met with in the cultivated canes; but, individually, the plants were often irregular in these characters. There is, in *Saccharum spontaneum*, nothing like the orderly development of the branches which characterizes *Saccharum arundinaceum*.

FORMULÆ AND MEASUREMENTS IN

1. *Formulæ of canes, shoots,*

Variety	Number dissected		Canes at harvest							Green shoots					
	Clumps	Plants	*a*	*b*	*c*	*d*	*e*	*f*	Total	*b*	*c*	*d*	*e*	*f*	*g*
Saccharum spontaneum: Coimbatore	3	8	1·0	2·7	5·5	4·1	1·4	0·4	15·1	0·2	0·5	1·5	1·5	1·0	...
Saccharum spontaneum: Glagah, Java	2	4	1·0	3·2	3·2	2·7	1·2	0·5	12·0	...	...	0·7	..	...	...
Saccharum spontaneum: Dacca form	4	9	1·0	5·8	10·8	7·8	2·3	0·4	28·1	...	...	...	...	...	...
Average of varieties	...	..	1·0	3·9	6·5	4·9	1·6	0·4	18·3	0·1	0·2	0·7	0·5	0·3	...
Saccharum arundinaceum	2	5	1·0	4·0	6·4	5·4	4·8	0·4	22·0	..	0·8	0·6	1·4	1·8	0·2

Species formulæ, Sacch. spontaneum, Matured canes 1 : 4 : 6 : 5 : 2 : 0·4

Sacch. arundinaceum, do. 1 : 4 : 6 : 5 : 5 : 0·4

2. *Length of basal part, and length and thick-*

Variety	Average length of basal part, in inches						Average length of joints: Number of canes measured					
	a	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*
Saccharum spontaneum: Coimbatore	1·2	0·5	0·5	·6	0·6	0·6	6	16	31	21	3	1
Saccharum spontaneum: Glagah, Java	1·3	0·8	0·6	0·8	1·1	0·7	4	13	13	9	4	1
Saccharum spontaneum: Dacca form ...	1·8	1·6	1·7	2·0	2·7	..	11	57	100	66	13	...
Average	1·4	1·0	0·9	1·1	1·4	0·6	...	...	...	...	...	...
Saccharum arundinaceum	2·9	2·1	2·4	2·9	3·2	...	3	16	26	22	18	...

THE WILD SACCHARUM GROUP.

buds, deaths and runners.

Bursting buds						Deaths							Grand Total	Runners
b	*c*	*d*	*e*	*f*	*g*	*a*	*b*	*c*	*d*	*e*	*f*	*g*		
0·5	0·5	1·6	1·5	0·5	...	.	1·9	2·7	3·1	2·1	0·2	...	34·4	5·0
...	2 0	4·0	3·2	0·7	1·5	...	1·5	3·7	2·7	1·0	0·2	1·5	34·7	1·6
0·1	8·9	32·0	15·8	3·1	0·3	...	0·6	5·4	12·8	2·9	1·0	0·3	111·3	6·0
0·2	3·8	12·5	6·8	1·4	0·6	...	1·3	3·9	6·2	2·0	0·5	0 6	60·1	4·2
0·4	2·0	2·8	2·8	4·8	2·0	...	0·6	0·6	0·4	0·4	..	...	43·6	0

The whole branching system 1 : 5 : 15 : 24 : 11 : 3 : 1 Runners 4

do. 1 : 4 : 10 : 9 : 9 : 7 : 2 do. 0

ness of joints, in branches of different orders.

in the first two feet						Average thickness of canes at two feet from base											
Average length, in inches						Number of canes measured						Average thickness, in mm.					
a	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*	*a*	*b*	*c*	*d*	*e*	*f*
3·2	3·5	3·8	4·0	3·8	5·1	8	21	35	22	6	1	68	71	71	80	73	79
2·4	3·7	4·3	5·0	5·1	4·5	4	12	13	7	2	1	62	69	84	92	85	98
2·6	3·4	3·6	3·5	3·7	...	11	57	89	57	13	...	97	99	105	108	122	...
2·7	3·5	3·9	4·2	4·2	4·8	...	...	...	...	...	...	76	80	87	93	93	88
2·1	3·3	5·2	5·8	6·5	...	5	20	31	26	23	...	153	172	209	237	237	...

CONTENTS.

LIST OF PLATES.

FOREWORD.

THE great advances made in agricultural science during recent years, by the application of well-arranged series of experimental plots, has thrown somewhat into the background the importance of careful observations on the ordinary crops grown, and the lessons which can be drawn from their variations. The laying down of a series of experimental plots and tabulating their results at crop time is a comparatively simple matter, and the equally important regular observation of the plots at intervals is more laborious and is not always attended to. A well-known experimentalist has, indeed, asserted to the writer, that such observations are altogether *ultra vires*, and that the plots should be only visited when sowing is taking place and the reaping done. While something may be said for this point of view in permanent plots, when the results are recorded over a long series of years, we cannot regard it as justified for general work on our Agricultural Stations, when it is desirable to obtain definite results within as short a time as possible. It has been found that the periodic notes taken of experimental plots during growth, as was regularly done at the Samalkota Sugarcane Station by the author, were often quite sufficient to explain apparent anomalies in the results, thus saving years of repetition, and it was usually found that these results could be forecasted with tolerable accuracy some months before harvest. The present paper, prepared in 1917 for the Lahore meeting of the Indian Science Congress, emphasizes this side of agricultural research. As will be seen in the context, it is not intended in any way to discount the value of the experimental method, but to explain the fact that there are cases when it is inapplicable and that, in such cases, series of careful observations, although more difficult and laborious, may be attended with useful results. To quote a remark in *Nature* (p. 203, May 16th, 1918), "Dr. Balls' comments on the short article on 'Cotton-growing Statistics' in the issue of this journal of April 11th, opens up a wide and interesting feature in scientific research, namely, the value of observed data and their interpretation." Owing to the lack of space, and the general character of the work on the Cane-breeding Station at Coimbatore, we have not been able to introduce much experimental work in the plots. *Observations* have, however, been regularly carried out for the past six years, and several Memoirs have already been issued, giving some of the interpreted results of such observations. The present paper gives yet another instance of such work, and it has been decided to publish it practically as it stands, although obviously incomplete in some respects, in that there seems to be little prospect of the longer Memoir projected being completed. It is considered that the details given sufficiently demonstrate the method proposed.

COIMBATORE,
October, 1918.

STUDIES IN INDIAN SUGARCANES, No. 5.

ON TESTING THE SUITABILITY OF SUGARCANE VARIETIES FOR DIFFERENT LOCALITIES, BY A SYSTEM OF MEASUREMENTS. PERIODICITY IN THE GROWTH OF THE SUGARCANE.

BY

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[Received for publication on 9th December, 1918.]

I. SUMMARY OF LITERATURE ON GROWTH IN LENGTH OF THE SUGARCANE.

A WRITER in the *Louisiana Planter* of September, 1916, has drawn attention to the great growth in length of the sugarcane in the Southern States during the moist, forcing heat of July and August. He claims that, not infrequently, two to three joints are added per week and that these are well formed and from four to six inches in length, "and are apparently much finer canes than are generally grown in the tropics." A further statement in the November number of the same journal gives the data on which these figures are based and, incidentally, throws light on the vegetative period in this tract. Careful measurements made by a planting correspondent, extending over four years, show that the cane is about a foot long at the beginning of July, increases by 30 inches both in July and in August, 18 in September, 12 in October, and then practically ceases to grow. The author draws attention to the economic importance of this class of work, especially with regard to the decision as to which canes are best suited to different tracts of country. He emphasizes the absence of exact data and suggests that such work should be taken up by the experimental stations. The method employed by the planter was very simple, in that stakes were driven into the ground and the canes laid along these at successive periods and measured.

Studies in the growth in length of the different parts of the cane plant have occupied workers in Java at intervals for many years, although the

 1

importance of the subject from the factory point of view has barely been realized. Kobus[1] (1887–1893) made a study of the growth in length of the lamina, and gave details as to the extent to which the inner structure was completed in leaves of different length. He pointed out that the lamina attained its full growth far sooner than the sheath. We have not had the opportunity of seeing Kobus's papers, and quote this from that of Kuijper mentioned below. Kamerling[2] issued an important paper in 1904, and quite recently Kuijper[3] has returned to the subject in 1915, and these papers deserve careful reading.

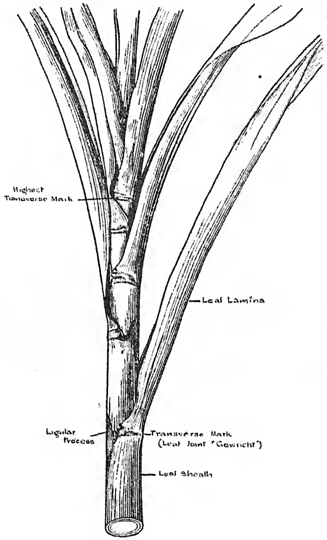
One of the greatest difficulties in measuring growing canes is due to the fact that the portion in actual elongation is permanently enswathed in a mass of leaves which cannot be removed without disturbing the growth. Observation of the ends of these leaves cannot be used in measurement because of the constant variation in length of successive leaves during the growing period. It becomes necessary to find some definite external point on the shoot which bears a constant relation to the growing point of the stem within. Kamerling set himself to find such a point. His object was to study the rate of growth in different fields and varieties, and to replace the general terms in use, such as "rapid," "slow," "moderately slow," and so on, by exact measurements, at the same time pointing out the importance of such work for the factory. By determining the rate of growth under certain well-defined conditions, he claimed that we should be in a position not only to decide the fitness of a variety for its locality but also to fix on general measures whereby unsatisfactory growth might be remedied. He first of all found that there is a sequence of growth in length in the lamina, leaf sheath and stem of a very definite character. The lamina first grows in length, rapidly unfolds itself and ceases from any further increase; as soon as this is completed, the energy of growth is transferred to the sheath. It quickly elongates and pushes the lamina into the air and light and, in its turn, ceases from further growth in length. Lastly, when the leaf sheath has finished growing, the stem internodes, hitherto merely a series of flat, superposed discs, suddenly elongate by the expansion of their cells and cease to grow in length after a very short time. The sheaths thus complete their growth in length before the internodes commence to elongate, and their further apparent growth is due to the increase

[1] Kobus, J. D. Bijdrage tot de kennis van den bouw en de ontwikkeling van het suikerriet, I and II, Nos. 19 and 30 of the *Mededeelingen van het Proefstation Oost-Java*, 1887–1893.

[2] Kamerling, Z. De lengtegroei van het riet, *Archief voor de Java-Suikerindustrie*, deel XII, 1904, page 997.

[3] Kuijper, J. De groei van bladschijf, bladscheede en stengel van het suikerriet, *Mededeelingen van het Proefstation voor de Java-Suikerindustrie*, V, 8, 1915.

in length of the internodes to which they are attached. In the young shoot each leaf sheath is entirely covered by the one outside it, while it is yet undeveloped, but the moment when it emerges from this protection Kamerling shows to coincide with its cessation of growth. The tops of two successive sheaths are now close together, and any further separation is due to extension of the stem which at this period commences to elongate. The top of the leaf sheath is the place where it joins the lamina, and Kamerling selected this point which he calls the "blad-gewricht" (leaf joint), as the one by the observation of which he could indirectly observe the growth in length of

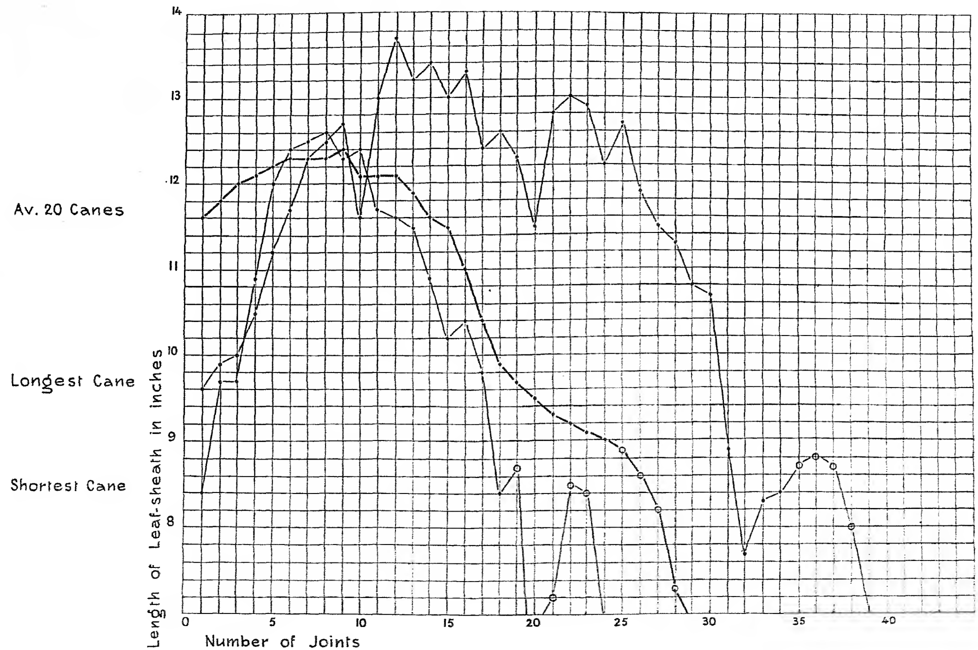


young joints of the stem apex (*see* Fig. above). This demonstration of Kamerling's has been found to be justified, *on the assumption that all of the mature leaf sheaths are of equal length.* He measured a series of leaf sheaths in different canes and soon found that, while the differences in their length in fully grown parts of the cane plant were very small, both at the beginning and end of the vegetative season the leaf sheaths were of different sizes. The first sheaths are very small, these successively increase in length until they reach a fairly

uniform maximum, and this is maintained during active growth. Towards the end of the season, however, the sheaths again diminish in length. He made a distinction between the actual growth of the young internodes, and their "apparent" growth as judged by the observation of the leaf joint, and showed that, while the difference between the actual and apparent growth is small during the period of full growth of the cane plant, it is large at the beginning and the end of the season. Kamerling then tried a method of measuring the growth of the stem directly, by removing the leafy mass around the actively elongating portion, marking it and covering it with tin foil, and measuring it again after 24 hours. The results agreed with those already obtained, showed that the region of elongation was confined to few joints, and that, in these, the top of each joint ceased growing first and the lower part continued elongating after the upper had ceased to alter, that is, that the region of most active growth in length in each joint was basi-petal. But such harsh treatment of the young growing parts soon introduced irregularities in development, and Kamerling's main results depended on the indirect method mentioned above.

To Kuijper belongs the credit of overcoming once and for all these difficulties. After trying various methods, he hit upon the ingenious plan of piercing the whole growing shoot with a darning needle (finer instruments encountered too much resistance), starting with a full-grown leaf sheath on the outside, which showed no further movement, and working upwards. A series of holes were thus made through the whole mass of growing parts, and, as growth took place, these holes were pushed up in various degrees in the different organs inside. After a period of six days the relative position of the holes was studied, and their change in position gave an accurate measure of the growth which had taken place in each organ. By a multiplication of the initial holes at distances of about one centimetre up the outer leaf sheath, he was able to state definitely in what part of each organ growth was most rapid, as all that remained to be done was to dissect out the mass after a stated interval, lay out the parts, and measure the vertical distances between the holes. While this method was found to disturb the growth in very young parts, it fully justified its use, and the general results obtained by Kamerling were substantiated, but, by a series of *actual*, in place of *inferred*, measurements. The basi-petal tendency of the zone of most active growth in each internode was confirmed, and it was found that the leaf sheath and lamina behaved in a similar manner. Kuijper's work was, in the main, instituted for a study of certain diseases of the shoot, which appeared to depend on the relative growth of the young parts, and the previous work of Kamerling

Length of Leaf-sheath Curves in Khari, Sabour, 1916-17



did not give the accurate figures required for this. He fully endorsed the selection of the uppermost visible leaf joint for measurement in stem growth, safeguarding it, as was done by Kamerling, at the beginning and end of the season. We are indebted to him for the first clear demonstration of what goes on inside the growing portion of the cane shoot.

An interesting piece of work on the growth of the cane was done by Taluqdar at Sabour Government Farm in 1914.[1] Here iron stakes were driven into the ground to a great depth, at the commencement of the season, and marks made to indicate the original ground-level. Measurements were taken from this point to the leaf joint, at intervals of a fortnight, in a series of cane bushes belonging to three different varieties, *Khari*, *Shakarchynia*, and *Buxaria*. Taluqdar followed the Java practice in selecting the leaf joint, but used a coloured mark which occurs across the base of the lamina at this point. This he calls the "ligular band," and in previous Memoirs we have termed it the "transverse mark" on the leaf sheath; it is usually quite easy to see and is often brightly coloured, forming one of the most striking features in the growing shoot (Fig. on p. 157). There appear to us to be two points in which the accuracy of Taluqdar's measurements may be criticized. In the first place his observations commence very early in the life of the plant and continue to the end of the growing period, and he does not appear to have noted that the lengths of the leaf sheaths diminish at these periods. He assumes a steady uniformity in length of leaf sheath throughout the growing period. Secondly, the work of the Java men was done on thick tropical canes, such as *Cheribon*, *Lœthers*, *P. O. J. 100*, and these differ a good deal in many respects from the indigenous Indian canes used by Taluqdar. It is by no means certain that the ends of the leaf sheaths are a safe point on which to base the measurements of stem growth in Indian canes. In fact, the leaf sheaths appear to differ in length very much more in the latter class of canes. Some measurements, made by the author, of successive leaf sheaths in *Khari* growing at Sabour, are appended. The average curve of the length of leaf sheath in the whole twenty canes measured has been plotted out and the curves of the longest and shortest canes have been added, *i.e.*, those with the greatest and smallest number of joints (Plate I). It will be seen that the leaf sheaths vary very greatly in the general curve during the course of growth, whereas, in the individuals, there are often differences in successive joints of over an inch. An analysis of these curves may make our meaning clearer. Leaving out the first five, until the leaf sheath has attained to its full length, and the last eight, when the leaf

[1] Taluqdar, J. M. Notes on the growth of Sugarcane. *Bihar and Orissa Agricultural Journal*, Vol. III, No. 1, April, 1915.

sheaths rapidly diminish in length owing to the immaturity of the joints, we have the following differences in the length of leaf sheaths. The average difference in length of adjoining leaf sheaths, in the shortest cane, is 0·44″, and the five greatest differences are 1·4″, 0·7″, 0·7″, 0·7″, and 0·6″. In the longest cane, the average difference is 0·59″, and the five greatest are 1·8″, 1·4″, 1·3″, 1·3″, and 1·1″. Compare with these figures those obtained from the three examples, given by Kamerling, of thick canes grown in Java:—

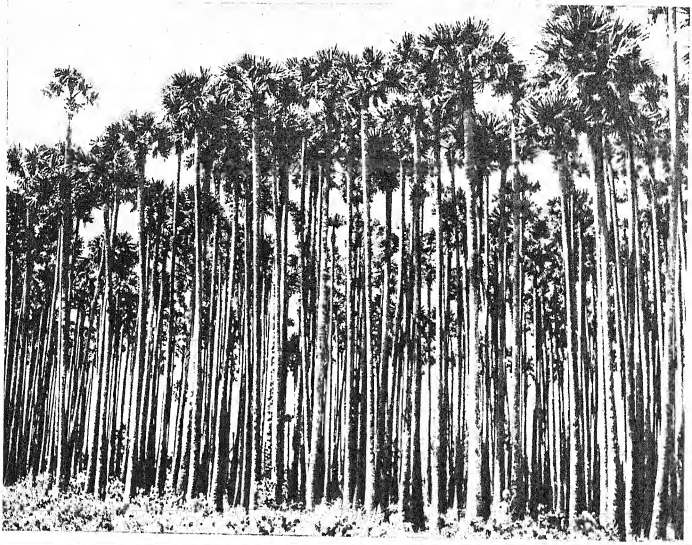
(1) Average difference 0·11″, the five greatest being 0·3 , 0·2″, 0·2″, 0·1″, 0·1″.
(2) „ 0·23″, „ 0·6″, 0·4″, 0·4″, 0·4″, 0·2″.
(3) „ 0·02″, „ 0·1″, 0·0″, 0·0″, 0·0″, 0·0″.

It appears from this that it might be well for Kuijper's work to be done again in a series of indigenous Indian canes, and, until this is done, it is unsafe to use the Java method for the accurate measurement of growth in length of young internodes by merely observing the distances of successive transverse marks.

Taluqdar's measurements extended from May to early November, but as the period of tillering was not completed until the beginning of June, the earlier measurements only refer to a small number of shoots, while at the end of the season very many had been destroyed by moth-borers. Five or six months may be taken as the period of active growth, and this received an enormous impetus in July when the rains set in, thus presenting great similarity with the course of events already referred to in Louisiana. An attempt is made to determine the influence of temperature and moisture on growth, and the general conclusion arrived at is that these two factors act in common and that, as soon as one of them declines, the effect of the other is neutralized. In the tables it is seen that the period of growth is limited at both ends by declining warmth and moisture. Growth in the tropics is very different from that in Louisiana and North India, in that the temperature there never sinks so low as to be ineffective and, when moisture fails, irrigation is resorted to. The usual period of growth is twelve months and, consequently, larger crops are obtained.

II. The method of cane measurements adopted and the material used.

The method adopted in this paper is altogether different from those referred to above. It is, namely, to take the cane at crop time and measure the parts, and from these measurements to try and infer the general growth conditions at the place where the crop was grown. The length and thickness of the different organs vary much in different places, and, from their study, it is attempted to form an opinion as to the relative suitability of such places



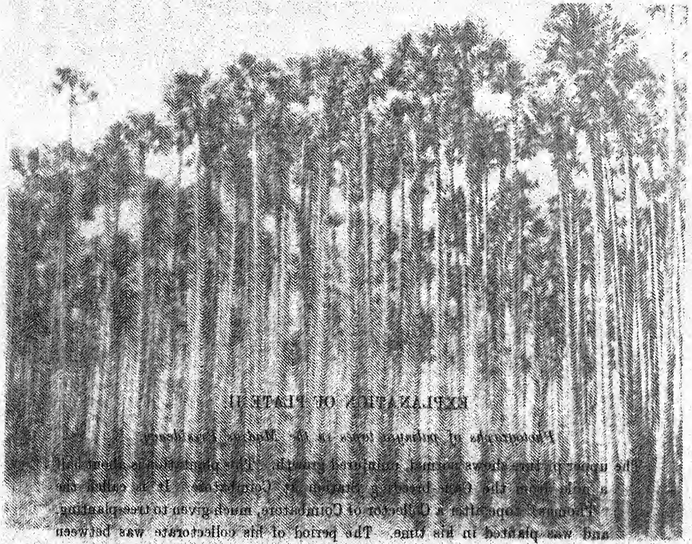
EXPLANATION OF PLATE II.

Photographs of palmyra topes in the Madras Presidency.

The upper picture shows normal, uninjured growth. This plantation is about half a mile from the Cane-breeding Station at Coimbatore. It is called the "Thomas" tope after a Collector of Coimbatore, much given to tree-planting, and was planted in his time. The period of his collectorate was between March 1848 and May 1862, and the tope is therefore 60 to 70 years old.

The lower picture shows the effect of a great storm of wind in a palmyra tope in the Godavari District. The storm occurred some 28 years before the photograph was taken (*see* Note on p. 161), and its effect is seen in the simultaneous bending of many of the stems in one direction.

PLATE II



to the varieties grown. This method was not adopted because there was any special fault to be found with those described above, but simply because it was the only possible one in the circumstances and for the purpose in view. In place of periodic observations made on a few selected plants during their growth at one place, a large series of plants grown at widely different stations are compared. Early in the life of the Cane-breeding Station it was noted that, as one passed from the frost-visited region of the Punjab, in a south-easterly direction along the Himalayas and in a southerly direction down the Peninsula, one constantly met with larger varieties of canes, even when these belonged to the same natural groups. It was easy to suggest that this was, in the main, due to the forcing effect of the warmer, moister climate. And seven North Indian canes of those collected at Coimbatore were distributed to Taliparamba, on the Malabar coast, and Samalkota on the Coromandel, in order to note the effect on these varieties of the soil and climate. A scheme of accurate measurements was instituted towards crop time, and these soon showed that there were marked differences in the growth of the plants in these two localities and at Coimbatore itself. Later on, these measurements were introduced for the study of the varieties in different parts of the country, including places in North India, and there are now ten localities from which we have a series of such measurements recorded. With this mass of material available, it was thought worth while to see if some expression could be evolved by which the influence of each locality on the growth of the cane could be distinguished.

That, from the study of the various parts of such a completed plant, some insight may be obtained into its vicissitudes during growth, is not altogether unreasonable. Any one accustomed to the study of growth rings in dicotyledons is aware that they differ according to variations in the year's season and those of successive years. At certain places in the Madras Presidency, all the palmyra palms may be seen suddenly to narrow at about the same distance from the ground, or to show a marked bend in the same direction, indicating surely that, at that period of growth, the young plantation encountered some storm or period of stress[1] (Plate II). In the cane itself it has

[1] Since writing the above, Mr. W. McRae, the Madras Government Mycologist, has very kindly placed at my disposal a photograph taken by him of a palmyra tope, showing the effect of a storm; and he has given me the following note concerning it: "The photograph of the palmyra palms with bent trunks was taken in October 1911 in the village of Mallavaram, in Cocanada taluk of the Godavari District. The tope was situated near the sea-shore. The palms were said by the village Munsiff to have been bent over in a storm that occurred 28 years ago, and he was able to fix the date because it happened in the same year as an important domestic occurrence."

been noted, in parts of Bengal, that it is easy to put one's finger on the part of the stem where the growing cane experienced the onset of the monsoon rains, whether because of differences of thickness and length of joints or the occurrence of abundant aerial roots. So too, the attack of a single moth-borer leaves its mark in a sudden diminution in thickness and length of the joints, those succeeding gradually recovering their normal size. The leaf scars of many dicotyledons engrave the history of the year's growth on the stem whether it be the slow growth of spring, when the scale leaves gradually change into foliage leaves, the putting forth of the branches, the rapid growth in the summer or the slowing down in autumn. So too, although less evident, there will be marks left in the joints of monocotyledons. My Assistant, Mr. T. S. Venkataraman, has shown that, in some coconuts growing on the Cane-breeding Station, there is periodicity in the vertical width of the bases of successive leaves, possibly connected with the seasons of the year, a fact which receives additional interest from the periodicity recorded below in the sugarcane itself. The mere study of the length of successive joints in a cane may therefore sometimes be of use in indicating differing growth conditions and some striking instances of this will be mentioned during the course of the paper. But many other measurements have been made as well, from which similar deductions could be made.

The system of measurements employed is fully described, and numerous examples are pointed, in Memoir No. 3,[1] but a summary is here given for the sake of clearness. As is natural, the chief importance is attached to the growth in length of parts. Twenty canes are chosen to represent any plot, safeguards being introduced to insure that they are average healthy ones at a distance from one another. These are first measured joint by joint as to length of lamina, leaf sheath and joint, and the results are so arranged that it is easy at any time to pick out the successive organs belonging to any one cane of the twenty. By a system of averaging (the difficulties of which need not detain us here), an ideal cane is built up for these twenty, and this is taken to represent the particular variety grown at that time and place. The measurements thus obtained are plotted out on squared paper and placed on record, as the appropriate curves of length of successive joints, leaf sheaths and laminas. Reference may be made to the curves already shown of *Khari* leaf sheaths

[1] Barber, C. A. Studies in Indian Sugarcanes, No. 3. The classification of Indian canes with special reference to the Saretha and Sunnabile groups. *Mem. Dep. Agric., Ind., Bot. Ser.*, Vol. IX, No. 4, May, 1918.

grown at Sabour in 1917 (Plate I). Besides these measurements in length of organs, the numbers of joints are counted and the total length of formed cane is measured, and from these two figures is obtained the rate of cane formation per mensem while in the ground. The numbers of dead leaves are counted and the length of the cane covered by these (these two figures being taken as indicating the rate of ripening of the cane), the length of the shoot (unripened part of the plant) is recorded and the total length of the whole plant when laid out on the ground, the maximum width of the leaf and the average thickness of the stem. The latter measurement deserves special mention, in that canes vary in thickness in different parts and are generally oval in section. Each cane, when stripped, is measured at the middle, at the base, and at the highest matured joint. And these measurements have to be done in two planes, at right angles to one another, because of the ovalness of the cane, one being made in the plane of leaf attachment and one at right angles to it. The latter is almost invariably narrower than the former. These six measurements are averaged for each of the twenty canes, and the resultant of these is taken as the average thickness of the canes in the plot. Incidentally, ovalness of the cane is recorded, as the cane varieties differ in this respect, as well as the tendency to thicken upwards or downwards which characterizes different kinds of canes. All of these measurements are made on the same twenty canes, and the latter are so arranged in tables that all the measurements of each individual cane and joint may at once be seen, and any future work on correlation between the variations in size in different organs may be studied.

This material forms the basis of our work, and a comparison of these measurements determines the general lines on which our conclusions are framed. It becomes possible to compare the growth of the same cane in different places, the development of individual cane characters in different surroundings, and the manner in which different sets of conditions impress themselves on cane growth in general—whether favourably or the reverse.

The series of measurements obtained for each set of twenty canes, taken at one time and place, form together a "unit" observation. There are now some hundreds of these units collected, and many of them were utilized in the Memoir referred to above, for the purpose of distinguishing the growth characters of the Saretha and Sunnabile groups. But, in the present paper, only those dealing with the seven cane varieties distributed to Taliparamba

and Samalkota have been included. Eighty-nine unit observations on these varieties form the basis of the present paper.

The varieties dealt with are the following :—*Saretha*, *Chin*, *Khari*, *Chynia*, *Pansahi*, *Baroukha* (of Sabour and not of the United Provinces, a member of the Nargori group of canes), and *Mungo*. All of these have been examined at the Cane-breeding Station, at Taliparamba and Samalkota, and such of them as were found growing at the Coimbatore Central Farm, Nagpur, Sabour, Pusa, Partabgarh, Shahjahanpur, and Aligarh. The observations at the latter place are less complete, in that only six canes were measured and these at an early stage of growth, but they are included because they indicate certain well-marked characters which have still to be checked. A study of the agricultural conditions and the curves of growths obtained have led us to divide these places into three regions: (1) The Coimbatore Central Farm, Taliparamba, Samalkota and Nagpur represent *wet land*, continuously irrigated from tanks; (2) The Cane-breeding Station, consisting of slightly saline *garden land*, dry land irrigated from wells; (3) Gangetic alluvium. The latter region has of necessity been less fully studied than the rest, and in many cases the record is very incomplete. There are great variations in the curves obtained from these northern places, but it has not been found possible, with the data available, to subdivide the tract. Suffice it to say that there appear to be as great differences in growth in North India as in South India, and that the rate of growth appears to be greater in Aligarh, Shahjahanpur, and perhaps Sabour, than at Pusa and Partabgarh. The last named gives, in almost all cases, a less vigorous growth than in any other place of those observed. The Cane-breeding Station, with its handicap of well-irrigation and intractable soil with slight salinity, shows curves much more similar to those obtained in North India than any of the wet land places, thus justifying its selection for the work of raising seedlings for North India. It has been already stated that our record is to a certain extent incomplete. This was of necessity the case, in that the work of accurate measurements has gradually extended, and the object of the present paper was not at first held in view. But it is held that this will not invalidate the method, which can be much more easily employed when the opportunity occurs of putting down the same varieties in each place. This incompleteness has, in the present instance, entailed a great deal of labour, in that there are a number of points which need safeguarding, lest conclusions are arrived at on insufficient data. A statement is appended of the observations on which this paper is based, showing the number of units obtained for each variety at each place, and some of the pitfalls are detailed below with the means adopted of avoiding them.

TABLE I.

Unit observations of varieties and places.

	Garden land	Wet land				Gangetic alluvium					Total
	C.B.S.	C. F.	Sam.	Tal.	Nag.	Sab.	Pusa	Part.	Shah.	Alig.	
Months in ground	11	10	11	8½	11½	8	7½	9	9	6	..
Saretha .	4	2	2	3	1	..	2	1	..	1	16
Chin .	3	2	2	3	1	..	..	1	3	1	16
Khari .	2	1	2	3	1	2	..	1	1	1	14
Pansahi .	1	2	2	3	..	2	..	1	..	..	11
Chynia . .	1	1	2	3	..	2	2	..	..	..	11
Baroukha .	2	1	2	3	..	2	..	..	..	..	10
Mungo . .	2	..	2	2	..	1	2	..	1	1	11
Total .	15	9	14	20	3	9	6	4	5	4	89
Garden land	15	Wet land			46	Gangetic alluvium				28	89

In comparing the general growth of the cane plant in different places, it is, in the first place, necessary to consider the varieties observed there. *Saretha* and *Baroukha*, for instance, are characterized by comparatively enormous length of stems, while *Mungo* is a dwarf variety with very short joints and canes. As the latter cane is present in some places and not in others, we cannot obtain reliable figures of general cane growth for any one place by averaging the observations irrespective of whether *Mungo* is present or not. It would, again, be difficult to compare the cane growth as indicated by the units observed at Nagpur and Sabour, for there is only one of our seven canes grown in common at these two places. The following method has been adopted to overcome this difficulty. Stations are only compared by averaging the same canes grown on them. The Cane-breeding Station, Taliparamba, and Samalkota were first compared, as all of them had the whole series growing. Then the Coimbatore Central Farm was compared with these three, omitting *Mungo* altogether, which was absent on it. Nagpur was compared with these four, as well as with Partabgarh and Aligarh, only in respect to the measurements of *Saretha*, *Chin*, and *Khari*. Sabour was compared with the three localities which had its five canes, Pusa with the same three, Partabgarh with the first four, Shahjahanpur with four, and Aligarh with three. This method of course greatly increased the work, but it was considered the only safe way in which to compare the general growth of canes in different places.

Another factor here obtruded itself. In comparing Pusa with the three places in South India which had the same varieties growing, it was noted that *Mungo* does rather well in some respects at Pusa, while it does very badly

in South India. As it is probable that most of the cane varieties now under consideration would do worse in Pusa than in South India, its comparatively good *Mungo* gives it a more favourable position than it deserves. And, in the general summation, such cases have to be considered.

Again, in comparing the growth of different varieties, we have to consider the general character of growth at the place where they are observed. Certain varieties are better suited to certain places, and it is part of the object of this study to determine what kinds grow best in each locality. Taliparamba, for instance, is characterized by the formation of many, longish joints, and long canes of moderate thickness; Nagpur has few joints of great length, but these are thin and the leaves are narrow; Partabgarh develops all parts poorly, excepting the thickness of the stem and width of leaf, and so on. It thus becomes important to take into consideration the range of places from which unit observations have been taken, in comparing the relative growth of the organs of different varieties.

Due allowance must be made for the character of the season and the piece of land used during any year. This is not usually possible or necessary, but some extreme cases have occurred, showing that the influence of these factors cannot always be neglected. The most striking instance of this is in the two sets of observations made at Samalkota in successive years. The curves of length of joints in these two years differ so much that they might well have been obtained from two different places, and they bear the impress of the season during which they grow so strongly that a separate section is devoted, later on, to their study. The difference in the plots of land in two years at the Cane-breeding Station is also clearly reflected in the series of measurements obtained, as has been fully detailed in the Memoir mentioned above. These differences in successive years make it all the more necessary that the observations should be extended over several years at each place. It will be seen, from a reference to the table of observation units, that there are a number of cases where only one observation has been made, and in such cases the results should be regarded as more or less tentative and to require checking by further observations.

The time during which the observed crop has been in the ground has, naturally, a very considerable influence on the relative growth which takes place, and this is emphasized by the fact that early growth is more energetic than that taking place later on. The period of growth has been carefully allowed for, in that various measurements in length have been divided by the number of months which have elapsed between the dates of planting and examination. Generally speaking, the plots have been examined earlier in

North India than in South, but the habit of trashing the cane at Taliparamba has made it necessary to make the observations earlier there too. Now a study of the relative length of joints at different periods of growth shows that, within a short time of the commencement of joint formation, these become very long, soon reaching a maximum, after which they gradually diminish till near harvest time. The joints in the earlier portion of the year are therefore longer than in the later, and the values in the tables for North India and Taliparamba occupy a more favourable place than they should do, when compared with other localities. This is especially the case with Aligarh where only six canes were measured, only six months old. The apparently high position of Aligarh is thus somewhat discounted, and similar allowance must be made in certain other cases. But, on the whole, when it is possible to check it by comparing canes growing during equal periods, it has been found that there is less discrepancy caused by this factor than would be expected.

It is a different matter when we consider the average length of season in different parts of the country. As is well known, the period of cane formation in North India is very much less than it is in the warmer, tropical parts. Whereas the season of active growth is very short in North India, often hardly reaching six months, it usually extends to nearly twelve in the South. The figures representing growth per mensem give a great advantage to North Indian stations, and this must be held in view when comparing them with the wet land localities and, especially, when considering the low place occupied by the Cane-breeding Station. After all, the total length of cane is the chief item to be taken into account, and not the enormous rapidity of growth taking place in North India during the months of heavy rainfall and great heat.

But, from the crop point of view, the amount of tillering must also be considered. It is probable that this is greater in the free, light soils of the Gangetic alluvium than in the heavy clays of the Peninsula.[1] But, although it is highly desirable for accurate figures to be obtained on tillering, it has not been possible to include this character in the general measurements taken. And a similar remark may be made as to the relative richness of the juice in different places.

The time at which the sets are sown is of some importance, as little actual growth takes place in North India until the rains come, excepting where there is abundant irrigation. The planting times vary, in our observations, from

[1] Some preliminary figures have since become available on this subject and are included in Memoir No. 4. *Mem. Dep. Agric., Ind., Bot. Ser.*, Vol. X, No. 2.

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January in Nagpur to April at the Coimbatore Central Farm. In South India the sets germinate within a week or ten days from planting and, if they do not appear then, it is often the custom to replant the field, but in North India one must sometimes wait for several weeks before there are any signs of the young shoots. To calculate the rate of growth, one should perhaps take the date at which the young shoots appear, because the protrusion of the leafy shoot is the first act of the germinating set, but we have at present no means of determining this date. To obtain a full picture of the relative growth in North India and the tropics, further observations will be necessary, and it may be well to divide it into definite periods as follows :—(1) Period of branching, during which the plant remains low and devotes itself to the business of tillering. This is probably a good deal longer in North India, where the thin canes have far more branches than the thicker South Indian varieties. (2) Period of active elongation of the stem, or cane formation. This is a good deal shorter in North India and probably cane formation is more rapid. (3) Period of ripening. This is better defined in North India, and is with difficulty separated from the growth in length in the South. The careful comparison of these periods in the North and South of India is a piece of work which is well worth doing.

It is, further, to be noted that, in this paper, only indigenous Indian canes are considered, and only a few of these, not perhaps very well adapted for the purpose, as they were the only ones readily available for comparison. There is little doubt that, if the series had been extended and, especially, if thick canes had been included, the differences between the two great regions would have been emphasized. As it was, many of the indigenous canes grown in South India were obviously handicapped by being in uncongenial surroundings, and this is ascribed chiefly to the heavy and impermeable nature of the soil, and the consequent difficulty experienced by the plants in obtaining moisture.

Lastly, the observations were confined to canes growing in Government farms. The conditions on these vary a good deal, much greater care being expended on the plots in some places than in others. It may usually be assumed that the cane growth is better on the farm than in the surrounding cultivators' fields, but this is not always the case. For instance, the wet land in the Coimbatore Farm, although good for paddy, is not specially suited to cane growing. It would not be selected by cultivators for that purpose. Similarly, the land in the Cane-breeding Station, which is eminently suited for compelling the canes to arrow, is not, as yet, sugarcane land. It is probable

that, in these two cases, the growth is inferior to that in the ryots' fields, and there may be other cases where a similar state of affairs exists.

Having due regard to these various pitfalls, it appears from our study that, first in importance, as influencing growth, is the local effect of the *place*, so much so that, within reasonable limits, it is often possible to form an idea as to what kind of canes and leaves are to be expected from growing any cane variety there. The annual variations in the *season* and *treatment* occupy a secondary place, but are sometimes very marked in their effect. Lastly, the *variety grown* sometimes dominates and, in some farms, the individuality of the variety counterbalances the effect of place and climate, as in the strongly growing *Saretha*, the dwarf *Mungo*, and, to a less extent, *Baroukha* and *Chynia*.

III. Characters of cane growth in different places.

From a study of the seven varieties, we have formed the conclusion that any of them at Taliparamba tends to have a large number of long joints; the length of cane formed per mensem is great and the growing season is long; but the canes are of only moderate thickness. The cane ripens quickly. The length of the shoot is great and the width of the leaf is considerable. The curve of joint length commences high, soon reaches its maximum, and that maximum is high. The general growth at Taliparamba is accordingly considered to be satisfactory, the only exception being that the canes are not very thick, and possibly tillering is defective. Taliparamba occupies the first place, in general vigour of growth, of all those at which measurements have been taken with these varieties.

We should naturally regard Samalkota, in the well-known sugarcane tract of the Godavari delta, as equalling Taliparamba in these respects. But, apparently, it is less suited for the growth, at any rate, of North Indian canes. There are only a moderate number of joints formed per mensem and these are of moderate length; the length of cane formed per mensem is thus only moderate and the canes are very thin, but the growing season is long. Ripening takes place quickly. The shoot is of moderate length but the leaf is distinctly narrow. The joint curve starts at a moderate height but is sometimes late in reaching its maximum and that maximum is only moderate.

Nagpur has very long joints, but very few of these are formed per mensem, and they are very thin; the season is long. Ripening is only moderately quick. The shoot is short but the leaf is broad, and so on.

Contrast with these the results obtained at Partabgarh. There are a moderate number of joints formed per mensem, but these are very short, and

the length of cane formed per mensem is small, while the thickness of the cane is not great. The season is short. Ripening proceeds very slowly. The shoot is very short, but the leaves are moderately broad. The joint curve commences low, does not reach its maximum very quickly and that maximum is low. Partabgarh, when compared with the other places noted, shows very poor cane growth. Its suitability for growing these varieties may be doubted, and may have something to do with the predominance of dwarf cane varieties of the *Mungo* type in its neighbourhood.

But, to give the full details of these characters in the various places will take too long, and a table is appended from which similar statements may be prepared for the other localities. The places are classified according to the development of each separate character, and are numbered in class order, the lower number generally indicating better growth, such as greater length or thickness, earlier ripening, and so forth. By averaging the development of all the growth characters in each place, we may, finally, obtain some idea as to general vigour of cane growth in each place.

TABLE II.

Growth characters in different places.

The ten places are marked 1–10 according to extent of growth.

	C.B.S.	C. F.	Sam.	Tal.	Nag.	Sab.	Pusa	Part.	Shah.	Alig.
Cane formed per mensem	10	6	5	1	7	3	9	8	3	1
Number of joints per mensem	9	8	6	1	10	3	5	8	4	2
Average length of joint	8	5	7	1	1	5	9	10	4	1
Average thickness of cane	5	3	9	6	8	2	1	7	3	(6)
Number of dead leaves per mensem	5	8	4	1	10	3	9	7	6	2
Length of cane bearing dead leaves	8	7	3	1	6	3	10	9	5	2
Length of shoot	9	3	5	1	8	6	2	10	7	4
Maximum width of leaf	4	4	6	1	2	4	3	3	4	3
Joint curve										
Height of curve at start	8	5	4	1	2	6	10	9	7	3
Distance of maximum from start	4	4	10	1	2	3	6	7	9	8
Height of maximum	9	1	6	1	1	7	8	10	5	4
Average	7·9	5·4	6·5	1·6	5·7	4·5	7·2	8·9	5·7	3·6

IV. The effect of locality on the growth of the different varieties.

A similar table has been prepared to indicate the comparative vigour of growth of each variety in each locality, from which an idea may be obtained as to the relative advantage of growing it there. This takes no account of the class of canes usually grown, nor of the character of the juice or *gur* produced, both of which will be of considerable importance in a final decision.

Table III.

Classification of vigour of growth in each variety in each locality.

	C.B.S.	C. F.	Sam.	Tal.	Nag.	Sab.	Pusa	Part.	Shah.	Alig.
Saretha	4	5	6	1	3	..	7	7	..	2
Chin	6	4	7	1	5	..	..	8	3	2
Khari	9	4	2	1	5	5	..	8	7	3
Pansahi	5	3	4	1	..	2	..	5	..	..
Chynia	5	1	4	3	..	2	5	..	..	..
Baroukha	5	2	4	1	..	3	..	..	..	..
Mungo	6	..	7	3	4	..	4	..	1	2

In studying this table, the previous one must be held in view, namely, that showing the general vigour of growth of all the varieties tested. A variety comparatively well grown among the local canes of a place, may otherwise appear low down in the list, owing to the poor growth of canes in general in it. The method should afford a ready and accurate means of testing the advantage of introducing a new kind. According to the table :—

Saretha grows well at Taliparamba, Aligarh and Nagpur; moderately well at the Cane-breeding Station and on the Coimbatore Central Farm; poorly at Samalkota; and badly at Pusa and Partabgarh.

Chin grows well at Taliparamba, Aligarh and Shahjahanpur; moderately at Nagpur and the Coimbatore Central Farm; poorly at the Cane-breeding Station; and badly at Samalkota and Partabgarh.

Khari grows well at Taliparamba, Samalkota and Aligarh; moderately at the Coimbatore Central Farm, Nagpur and Sabour; poorly at Shahjahanpur; and badly at Partabgarh and the Cane-breeding Station.

Pansahi grows well at Taliparamba and Sabour; moderately at the Coimbatore Central Farm and Samalkota; poorly at Partabgarh and the Cane-breeding Station.

Chynia grows well at the Coimbatore Central Farm and Sabour; moderately at Taliparamba and Samalkota; and poorly at Pusa and the Cane-breeding Station.

Baroukha grows well at Taliparamba and the Coimbatore Central Farm; moderately at Sabour; and poorly at Samalkota and the Cane-breeding Station.

Mungo grows well at Shahjahanpur and Aligarh; moderately at Taliparamba, Sabour and Pusa; and poorly at the Cane-breeding Station and Coimbatore Central Farm.

From the above summary we see that the individuality of the cane makes its mark throughout the series and, generally, there seems to be a tendency for the growth of varieties to be better near the native habitat of the cane, a result not without its significance.

Similar tables might be prepared, comparing the growth of these varieties and the development of their individual characters in the three regions, *garden land, wet land* and *Gangetic alluvium*, and so on; but it is considered that the three tables given will sufficiently demonstrate the method.

V. THE EFFECT OF THE SEASON ON THE LENGTH OF THE JOINTS.

Two sets of unit observations have been made at Samalkota in the Godavari District of the Madras Presidency, one during 1915-16, on canes ten months old, and the other during 1916-17, on canes 11 months old. On examining the joint curves of *Saretha* obtained in these two years, it is seen that they could not well be more different (Plate III). This fact caused a good deal of trouble, as it appeared generally to discredit the method adopted in this paper. In 1915-16 the first joints were short, they showed an irregular series of maxima and did not attain their greatest length until the 21st from the base, and this maximum was not great; but there were a large number of joints, so that the cane was long. In 1916-17 the first joints were long and quickly attained their maximum (at the 4th joint), this maximum was high, but the number of joints was small, so that, in spite of their length, the whole cane formed was rather short, although the plants had been longer in the ground than in the previous year. This 1916-17 curve was, however, similar to those obtained at other places. The curve of 1915-16 was altogether unique, and unlike that obtained at any other place. The general average joint curve, of all the 89 unit observations, has been added in the Plate for comparison.

Joint Length Curves, Saretha, Samalkota, in 1915-16 & 1916-17, & General Curve, of the Whole 89 Observation Units

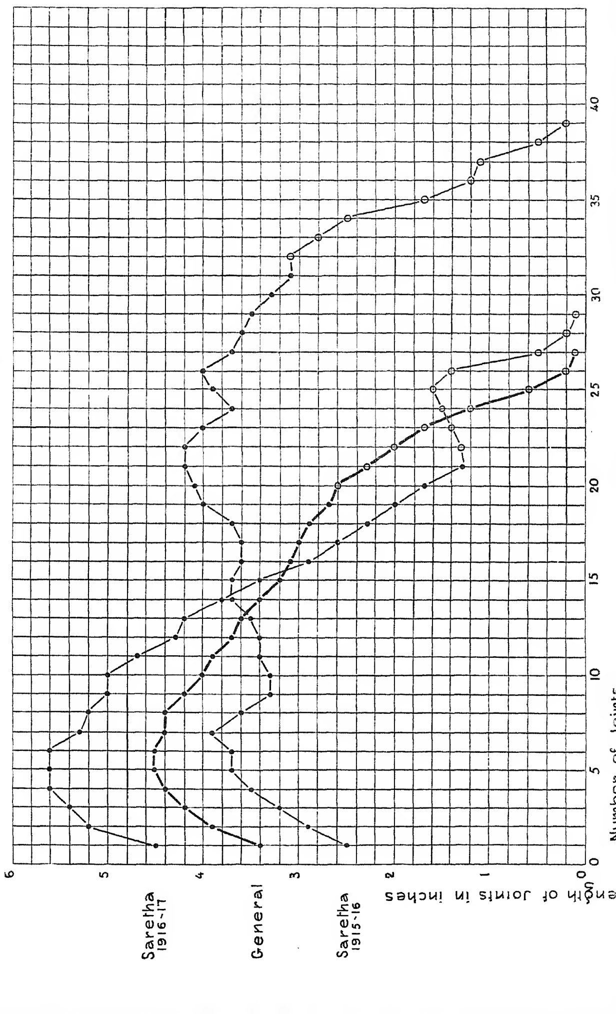
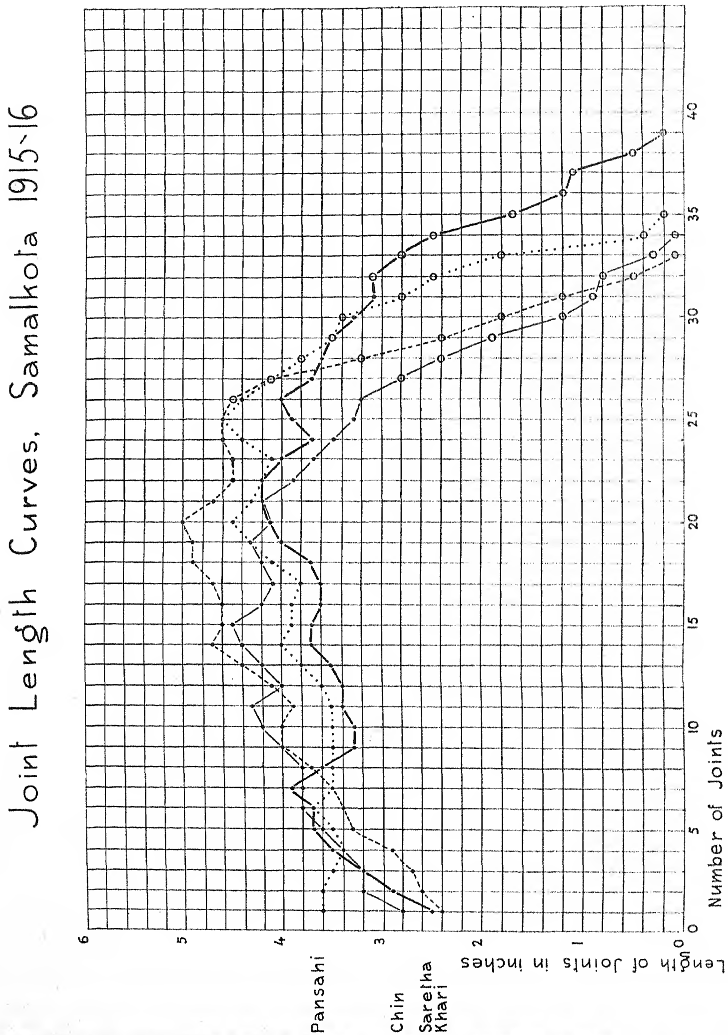
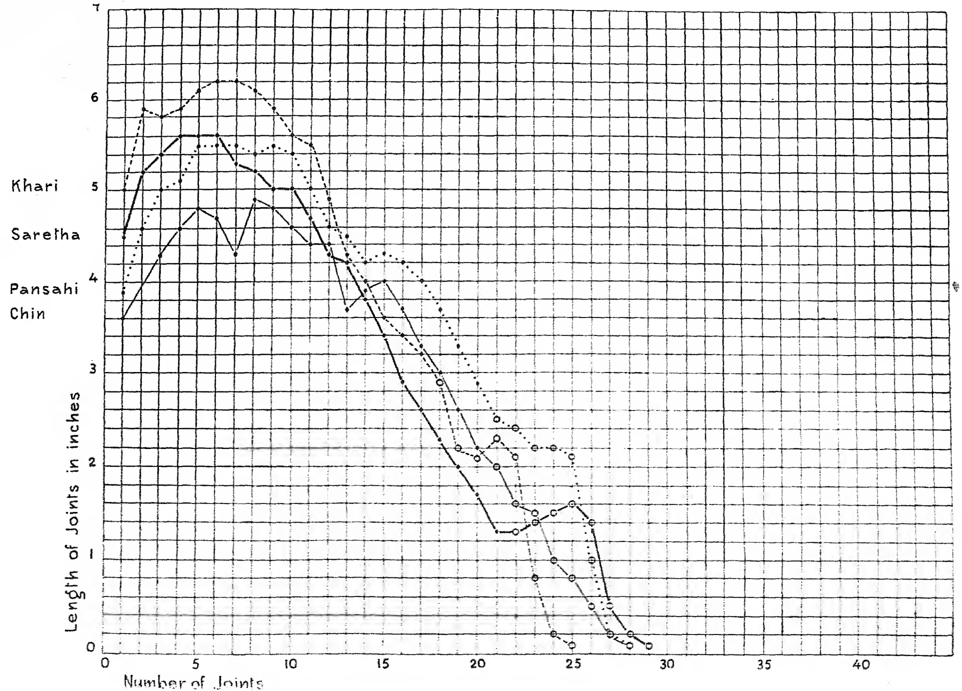


PLATE IV.



Joint Length Curves, Samalkota 1915-16
Number of Joints
Length of Joints in inches
Pansahi
Chin
Saretha Khari
0
5
10
15
20
25
30
35
40
1
2
3
4
5
6

Joint Length Curves, Samalkota 1916-17



Now, this difference was so striking that a full study was made of all the other North Indian varieties grown at the same time at Samalkota. It was seen that four of them shared the abnormal joint length curve with *Saretha* (Plate IV). The joint curves of *Saretha, Chin, Khari* and *Pansahi* were, together, quite unusual in 1915-16, but perfectly normal in 1916-17 (Plate V). A further examination was made of all the other measurements taken in the unit observations, and other differences were noted in these two seasons in various leaf and stem measurements. To clear up the difficulty, a reference was made to the published rainfall and irrigation reports of these two years at the Samalkota Farm.

The conditions in the Godavari delta are peculiar. The water-supply of the delta crops has two different sources: (1) The canals from the Godavari river, depending on rain in Hyderabad and Bombay; and (2) local rainfall, consisting of thunder showers in May and September, and the two monsoons, south-west from June to August and north-east from October to November. In the absence of details for Samalkota, the following analysis of rainfall at Cocanada and Ramachandrapuram, slightly nearer to the coast, may be taken to represent the delta conditions. The figures are for the 45 years before 1914.

TABLE IV.

Rainfall in the Godavari delta. Averages for 45 years.

	Dec.	Jan.	Feb.	Mch.	Apl.	May	June	July	Aug.	Sep.	Oct.	Nov.
Cocanada .	0·95″	0·18″	0·35″	0·42″	0·52″	1·82″	4·34″	6·00″	5·48″	6·10″	8·75″	4·17″
Ramachandrapuram	0·76″	0·07″	0·23″	0·40″	0·62″	1·88″	5·01″	6·54″	6·36″	7·31″	7·92″	3·69″

The average monthly rainfall may be extracted from the above table, for the periods mentioned above. The dry months, December to April, cold at first but gradually increasing in heat after February, 0·45″; May showers, 1·85″; south-west monsoon, June to August, 5·62″; September thunderstorms, 6·70″; north-east monsoon, October and November, 6·14″.

The canes are planted early in the year, during the middle of the dry, hot weather, and are irrigated by the Godavari canals. But the latter are closed, every year, for cleaning out the silt, for six weeks during May and the first half of June, in preparation for the flood water caused by the south-west monsoon in the area drained by the river. During this stoppage of the canal water, unless there are local showers in the delta (many miles from the collecting area of the river), the canes suffer a set-back, and many of them die. If the

monsoon is later or insufficient, the canals are opened late, and various expedients are resorted to, to keep the canes alive. When the canals are opened, there is abundant water for the rest of the growing period, the only danger being that of water-logging, because of too much rain in September to November. The printed summaries of the weather during the two seasons are quoted from the Samalkota Farm reports.

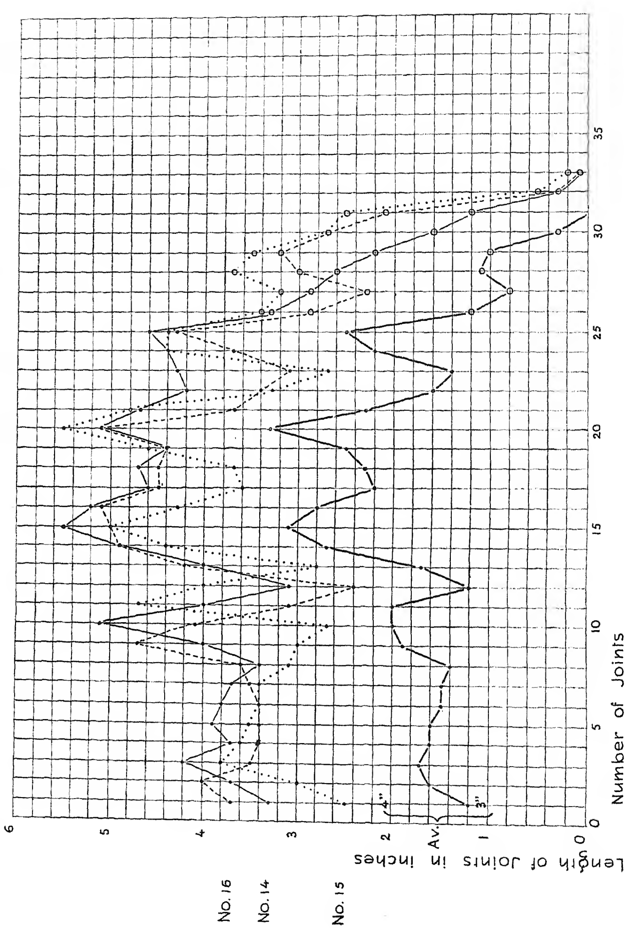
1915-16: "The rainfall recorded for the year was well above the average. The south-west monsoon was late in breaking, the first really heavy shower was not received till the 22nd June and the canals were late in filling........ The season throughout the south-west monsoon was characterized by short spells of rainy weather, followed by considerably longer spells (sometimes of more than a fortnight) of dry weather. The north-east monsoon rains were good and during the whole of November were fairly steady........"

1916-17: "The rainfall recorded during the year was well above the average. The south-west monsoon was very early in breaking, the month of June opened with very heavy showers, and the canals were full unexpectedly early........ The season throughout the monsoon period was characterized by regular and evenly distributed showers and want of rain was never felt. The heavy north-east monsoon rains in October, amounting to 11 inches, seriously interfered with the harvesting of paddy........ The harvest of the longer varieties was also caught in the heavy fall in the latter part of November."

Here we see that although in each year the rainfall was "well above the average," its distribution was very different in the two seasons. The first year was distinctly bad in its first half and good in its second, while the reverse was the case in the second, with its floods towards the end of the year. And these differences in the seasons are permanently engraved on the joint curves obtained. The character of the season was of such a nature that it obliterated the usual characteristic growth of the locality as well as any individual differences in these four canes themselves.

But, while this is so clearly shown in the four cane varieties mentioned above, there is little trace of it in the other two, namely *Baroukha* and *Chynia*. These canes appear to have been little affected by the early drought of 1915-16 and, indeed, their curves are characterized by excessive growth in the early part of the year, as if they were accustomed, or at any rate indifferent, to drought conditions in their early stages. The curves of all six varieties were in close agreement in 1916-17. We have thus a case in which the character of the individual may override that of the season.

PLATE VI.



Periodicity in Joint Length Curves of three Pansahi Canes with 33 Joints each

The average curve is lowered 2" for the sake of clearness

VI. Periodicity in the length of the joints.

An inspection of the general curve of length of joints given above (Plate III), shows that it is fairly uniform in its course. There are few ups and downs. After a comparatively high start it rapidly ascends to a maximum, it then descends gradually for some distance, while, in the last eight joints, the descent is rapid. As a matter of fact, the curve commences at 3·6″, which is the average length of the first joint above ground; the succeeding joints are longer and longer until they reach 4·5″ at the fifth joint; then the joints gradually decrease in length until, at the fifteenth, they are only 2·6″ long; the descent in the last eight is quick until the ultimate joint measured is 0·1″ long. These last eight are more or less immature joints at the top, for all canes are measured from ground-level to that joint at the growing tip which first falls to merely one-tenth of an inch in length; further measurements are not well possible in the field, and the foot-rule used is one divided into tenths of an inch. The curve is smooth throughout its length and there are few irregularities. It is made up of 89 unit observations of 20 canes each and is thus the resultant of over 50,000 separate measurements. It is different with the unit curves, some of which have been reproduced in the diagrams (Plates IV and V), these being the averages of only 20 canes growing at one time and place. The inequalities are greatly increased, and there are a series of ups and downs throughout the length of the curves. But, when we turn to the curves prepared for individuals of these 20 canes, these differences assume larger proportions, and it is not unusual for two consecutive joints to differ by as much as two or three inches in length (Plate VI). The greater the number of canes used in making up a curve, the more uniform is the curve obtained. The general summation curve is in this respect unlike any curve of the whole series, and neither it nor the ordinary varietal curves are to be regarded as *average* joint curves in the usual sense. They are representations of the usual course of events rather than a picture of the average cane of the plot. Such curves have been called elsewhere "ideal," as contrasted with average ones.

There are great difficulties in obtaining such a curve. One of these will readily occur, when it is remembered that the canes of any clump vary greatly in the number of joints, and it is therefore impossible to take an average of them in succession. Again, each cane varies a good deal in the length of its successive joints; some are long and some are short, and in averaging these it will often happen that the long joint in one cane will fall opposite to the short in the next. Any system of averaging will therefore have the tendency to smooth out the differences in different parts, and, the greater the number of canes dealt with, the smoother the resulting curve will be, as is seen in the

cases quoted above. But it is also obvious, if there is anything like periodicity in growth, a rotation of zones of longish and shortish joints following one another, that this periodicity, in any averaging, will also tend to be ruled out and leave little trace behind. We must therefore in this study hark back to the individual curves of separate canes. And, in noting the oscillations in length in successive joints, we must see that the canes compared have as nearly as possible the same number of joints. Three canes of *Pansahi*, grown at Samalkota in 1916, with the same number of joints, have been selected and their joint length curves plotted out on squared paper (Plate VI). The oscillations in these curves, as was to be expected, are very great, but we see at once that there is a regularity in these ups and downs in the three curves, so that we may easily pick out the successive maxima. There being an equal number of joints in the three canes, we can without difficulty average them, and we see that, at fairly regular intervals, there is a zone of increased growth in length, the maxima occurring at the 3rd, 10th, 15th, 20th, 25th and 28th joints. The 28th joint is in the region of those which have not yet completed their growth, while the 3rd is at the base of the plant where disturbances may well occur owing to earthing up and the omission of the joints below the surface. In the middle of the cane there is a regular periodicity in the growth in length of joints. Our example has, frankly, been chosen where this periodicity is rather clearly shown, but it will be seen directly that it is no isolated instance. A method has been devised, by which each set of twenty canes may be judged, as to any periodicity in the length of joints in the individual canes and in the whole series taken together (Plates VII and VIII). The twenty canes are arranged across the page and the number of joints in each cane is indicated by a row of equal squares, the cane with the greatest number of joints being placed at the top, and the others in succession below it, until the cane with the smallest number of joints is reached at the bottom. By this arrangement, any set of canes of equal length are placed together. The first diagram (Plate VII, fig. 1) represents twenty *Pansahi* canes grown at Samalkota in 1915-16, and, in this diagram, the canes numbered 14, 15 and 16 are the ones whose curves are given in Plate VI. The maxima in the length of joints, indicated in the diagram by circles, occur with a certain amount of regularity, the increment being most frequently at every fifth or sixth joint. Thus, in Cane No. 5, they occur at joints 2, 7, 13-14, 19 and 25; in No. 6, at joints 2-3, 8-9, 14-15, 20-21, 26 and 30; in No. 7, at joints 2, 5, 10, 15, 20, 32-33 and so on. Connecting lines have been drawn between the apparently related maxima in adjoining canes, namely, such canes as have the same or nearly the same numbers of joints; and, where such related maxima are

Periodicity in Joint Length Curves

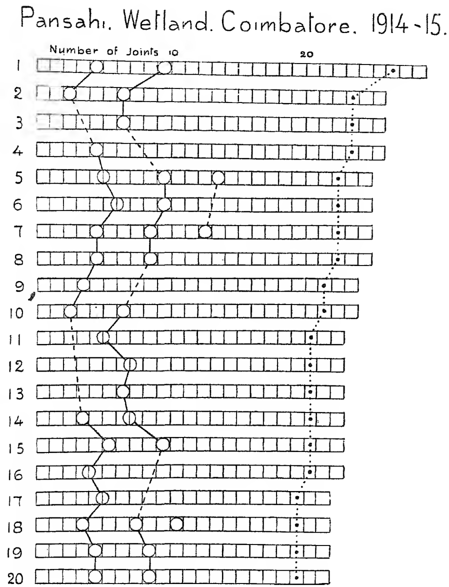


Fig. 2.

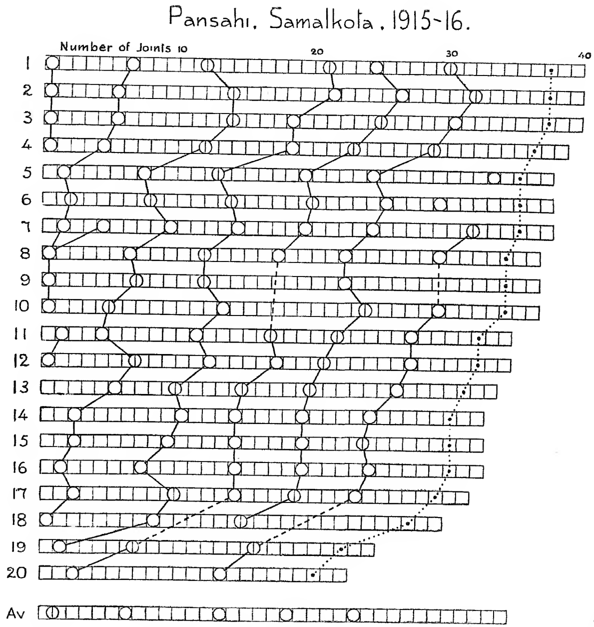


Fig. 1.

Periodicity in maximal joint length, *Pansahi*.

Pansahi, Wetland, Coimbatore. 1916-17.

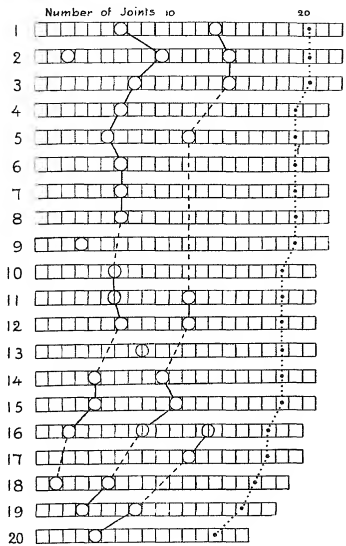


Fig. 1.

Baroukha, Cane-breeding Station, 1915-16.

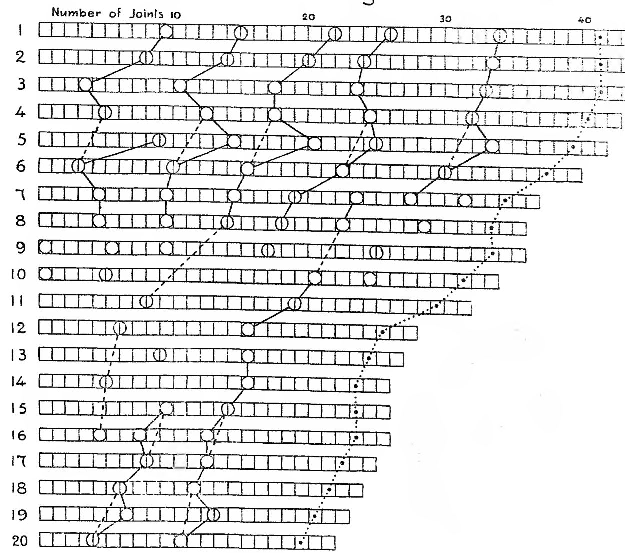


Fig. 2.

Periodicity in maximal joint length, *Pansahi* & *Baroukha*.

absent in adjoining canes, but present in canes slightly removed from one another, as in Nos. 8–10 and 8–11, the connecting lines are broken ones. Lastly, a dotted line is introduced towards the right of the diagram, which gives a general curve of the length of the twenty canes, as judged by the number of joints in each.

Now, it is interesting to note that the lines connecting related maxima in two adjoining canes are often more or less parallel, with one another *and* with the dotted line on the right. Parallelism can be traced, for instance, in the connecting lines between Canes 3 and 4, 4 and 5, 5 and 6, 7 and 8, 8 and 9, 12 and 13, and few adjoining canes are without traces of them. By somewhat arbitrarily joining up all the connecting lines throughout the series, we get a set of maxima curves for the whole twenty canes. In composing them, attention is paid to the undoubted tendency of the connecting lines to run parallel to the dotted line on the right. Although showing numerous irregularities, the general curves of maxima thus obtained are readily seen to be more or less parallel in their course with the curve indicating the length of the canes.

If the periodic stimuli indicated by these curves synchronize, it is natural to suggest their origin in some external cause, acting on all the canes together. If, on the other hand, they do not occur at the same time, we are thrown back on a natural periodicity of growth in the plant, which, in this case, tends to form longer joints once in every five or six. But we have some knowledge of the relative time of origin of these twenty canes. We have learnt elsewhere that the canes of a clump are often easily distinguishable into two classes, early and late in origin, and this shows itself especially clearly in the *Pansahi* group of canes.[1] Among a number of distinguishing characters, the first formed canes have a considerably larger number of joints than those emerging later from the ground. We are justified in assuming from this that the upper canes in the diagram, having the greater number of joints, are early canes, and those towards the bottom of the diagram are late. Arguing from these premises, we may suggest that the first four canes, being the earliest formed, have a very early maximum in length of joint. The next eight, arising somewhat later, have a slightly later first maximum. It is possible that the first maximum in these eight may synchronize with the second maximum of the first four, and this is independently suggested by the maxima curves. Similarly, the next four canes have a still later first maximum, and the connecting lines suggest that these synchronize with the second maxima of the second eight and the third of the first four. Lastly, the last

[1] Barber, C. A. Studies in Indian Sugarcanes, No. 2. Sugarcane seedlings, including some correlations between morphological characters and sucrose in the juice. *Mem. Dep. Agric., Ind., Bot. Ser.*, Vol. VIII, No. 3, July, 1916, p. 159.

four, very late canes, have few maxima, and their dotted line suggests that these synchronize with the later maxima of the preceding canes. If this reasoning has any foundation, we have a distinct support to the argument that the general curves of maxima in the twenty canes represent a succession of synchronous growth stimuli, which affect all the canes growing at the time, in other words, that the cause of the stimulus is external. We have been accustomed to look to the *Pansahi* group of canes for clearing up our ideas on many of the processes of growth in the sugarcane plant[1] and this would account for their showing this periodicity in growth better than in the other varieties examined. We have, in the above reasoning, merely attempted to show a possible explanation of the peculiarities in the position of the maxima of joint length. For any certainty to be attained as to the cause of this periodicity, whether external or inherent, the present observational method does not yield sufficient data. A simple series of experiments should be capable of determining the point at issue.

Of the dozen or so examples worked out, three others are added, in which the periodicity in the length of the joints of the cane is observable (Plates VII and VIII). Two of these are from *Pansahi* plots in the wet lands on Coimbatore Farm. In these, the numbers of joints are few and there are also few maxima. The periodicity, as explained above, is however distinctly visible, especially in the case in Plate VII. The variation in the number of joints in the twenty canes is small, and the end dotted line is accordingly more vertical than in the former case, and this uprightness of the curve is reflected in the general maxima curves of each series.

The last example is of *Baroukha* canes grown at the Cane-breeding Station in 1915-16 (Plate VIII, fig. 2). There are a large number of joints, and great variations occur in the twenty canes in this respect. There are also many maxima noticeable in individual canes. Although these are by no means so regularly placed as in the *Pansahi* canes, there is a distinct suggestion of periodicity in many cases. This is fairly obvious in the first eight canes and in the last six, but there are few maxima in the intervening six, and it is not possible to introduce connecting lines in them. There is, moreover, a lack of parallelism, in the diagram, between the connecting lines and the end dotted line. For instance, in Canes Nos. 1–3, with the same number of joints although the connecting lines are more or less parallel, they trend strongly to the left instead of being vertical. In Canes Nos. 3–5, an opposite direction is assumed, the end lines passing down to the left while the connecting lines pass to the

[1] Barber, C. A. Studies in Indian Sugarcanes, No. 4. Tillering of Underground Branching. *Mem. Dep. Agric., Ind., Bot. Ser.*, Vol. X, No. 2.

right. We may perhaps obtain some light on these anomalies by referring to Memoir No. 2, page 162, where it is shown that it is not possible to separate the canes in *Baroukha* into early and late, by the counting of the number of joints formed, as it is in *Pansahi*. It is therefore probable that the arrangement in the table is not that in order of emergence from the ground. Attention is, however, drawn to the broken lines inserted, as in Nos. 4–6, which are not infrequently parallel with one another and with the end dotted line. It is obvious that, if Canes Nos. 4 and 6 had been placed next to one another, the periodicity in the two canes would have been uniform. The same applies to 15 and 17 and to 18 and 20 and, in a slightly less degree, to 1 and 4, the connecting lines in each being approximately parallel with the dotted line. And it is possible that, if we had some reliable method of determining the order in which these canes emerged from the ground, we should be able to compose a diagram showing the periodicity more clearly.

PREFACE

The investigations recorded in the following paper were carried out at the suggestion of Dr. E. J. Butler, Imperial Mycologist, to whose guidance, ready advice and assistance I have been greatly indebted. My acknowledgements are also due to my colleagues in the laboratory for the help they have cheerfully given.

L. S. SUBRAMANIAM.

ALLAHABAD AGRICULTURAL INSTITUTE
LIBRARY.

A *PYTHIUM* DISEASE OF GINGER, TOBACCO AND PAPAYA.

BY

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Assistant to the Imperial Mycologist.

[Received for publication on 11th June, 1919.]

About three years ago, seedlings of tobacco (*Nicotiana Tabacum*) were found to damp off in large numbers in the seed beds. A few seedlings were incubated in a moist chamber. The next day there was a copious growth of a *Pythium* belonging to the *gracile* group (subgenus *Aphragmium*). It had the following characteristics :—Mycelium branching freely in all the tissues ; hyphæ 3 to 8μ broad, septate in the older branches and frequently with irregular swellings on the hyphæ, sporangia produced in large numbers, lateral, elongated, similar in shape to the hyphæ, slightly swollen at the tip when ripe, without a septum cutting off the sporangial stalk from the parent hypha ; zoospores of the usual *Pythium* type ; oogonia with oospores not completely filling the cavity, produced on lateral branches and on the hyphal swellings both intra- and extra-matrically. Boiled ants were floated in a dish of water and a piece from the incubated material was put in the dish. On the third day there was a good growth of the fungus on the ants. One of the ants containing the mycelium of the fungus was put in a glucose agar slant. The fungus grew well in this medium and subcultures from it gave pure cultures.

Raciborski[1] found a fungus, which he identified as *Pythium complens* Fischer (which is the same as *P. gracile* de Bary and cannot be distinguished from the earlier *P. monospermum* Prings.), attacking tobacco plants in nurseries which were weakened previously by the attack of *Phytophthora Nicotianæ*

[1] Raciborski, M. *Parasitische Algen und Pilze Java's*, 1 Thiel, p. 8, 1900.

van Breda. He failed to get successful inoculations on healthy tobacco plants. He did not give any details of the fungus, but only mentioned that he did not find any septum cutting off the sporangial stalk. Since *Pythium gracile* de Bary was previously only known as a saprophyte, he suggested for the first time the facultative parasitism of this species.

In July, 1917, seedlings of chillies (*Capsicum annuum*) were found to damp off in small quantities. The seeds were got from Bombay. The same *Pythium* was found to be the cause here also.

About the same time, a small ginger plant (*Zingiber officinale*) was found dying in a plot where ginger rhizomes were planted for experiments. The portions above the ground-level were withered. The collar had become very soft and rotten. On examination numerous oospores of a Phycomycete were found in the rotten leaf-sheaths at the collar. The oospores were smooth, thick-walled, and lying loose in the oogonium. Pieces of the rotten stem were incubated in a moist chamber. The next day a copious growth of mycelium with numerous sporangia of a *Pythium* belonging to the *gracile* group developed. Later on oospores also were produced, and these oospores agreed with those found on the plant itself before. This fungus was found to be identical with that causing "damping off" on tobacco and chillies. Pure cultures were taken in the same way as in tobacco.

Butler has previously mentioned[1] that a species identified as *Pythium gracile* Schenk (not de Bary) causes a serious disease of ginger plants near Surat (Bombay). It was pointed out, however, that it is not now possible to be quite certain what fungus Schenk had under study, as he did not describe it fully and there are several allied forms difficult to distinguish from one another. The symptoms by which the disease can be recognized are a withering of the leaves and a softening of the stalks at the collar though not to such a degree as to make them fall over. Specimens preserved in the Pusa Herbarium show that the Surat fungus agrees with that now under consideration. It was not cultivated and no inoculations were carried out.

A form found killing castor plants (*Ricinus communis*) in water culture in India[2] is perhaps the same.

In 1908-09 McRae[3] investigated a disease of ginger in Rangpur (Eastern Bengal) locally called "Jaindhara" and identical with the Surat disease.

[1] Butler, E. J. "An account of the genus *Pythium* and some Chytridiaceæ." *Mem. Dept. of Agric. in India, Bot. Ser.*, I, No. 5, 1907, p. 70.

[2] Ibid.

[3] McRae, W. "Soft rot of ginger in the Rangpur District, Eastern Bengal." *Agric. Journ. of India*, VI, 1911, pp. 139–146.

There also a *Pythium* was found in all diseased plants. Slabs cut out with a red hot knife from the interior of stems that were only slightly diseased, and grown under aseptic conditions, gave pure cultures of the *Pythium* only. He did not carry out inoculation experiments.

McRae studied the field characters of the disease in detail and gives the following account of it :—" The first outward indication of the disease in the growing crop is a general but slight paleness of the leaves of a shoot, then the tips of the leaves turn yellow, and this yellowing gradually spreads along the leaf towards the leaf-sheath, often more rapidly along the margins. Then the leaf-tissue dies and becomes scarious from the tip, the dead area gradually extending towards the leaf-sheath following in the wake of the yellowish discolouration. The leaves droop and hang down along the stem, till finally the whole shoot becomes dry and withered. Meantime the collar, that part of the aërial stem between the place where it arises from the rhizome and where it emerges from the ground, becomes of a pale, translucent brown colour, and, by the time the leaves are well yellowed, it is very watery and soft so that the whole shoot can easily be lifted off, breaking away at this point though not falling over spontaneously. This soft rot also extends beyond the collar into the rhizome. The rotting is accelerated by the combined action of other fungi and of small eelworms and the larvæ of flies which act as secondary agents. Both the discolouration and softening extend to the whole rhizome, which gradually rots and disintegrates, forming a loose watery mass of putrefying tissue enclosed by the tough rind. The vascular strands lie isolated inside. The roots attached to the affected parts also present the same symptoms."

During the last few years, numerous cases of an obscure disease like the " foot rot " of *Citrus* trees were observed on papaya trees (*Carica Papaya*) in the vicinity of Pusa. It has also been reported from Kathiawar (Western India), Dacca and Burma. Especially during the rainy season of 1909 the disease was very severe in the kitchen garden of this Institute.

The first indication of the disease is the wetting of the bark at the region of the collar and softening of the tissues with a copious exudation of latex which turns brown on coagulation. The patch expands gradually on all sides, sometimes to two feet in length from the base upwards. The tissues inside get discoloured and rotten and give rise to a foul-smelling mass wherein maggots breed in large numbers. The decay travels through the bark into the cambium and thence into the wood, causing rot as it progresses. This rotting continues as long as the weather is damp but is checked by dry weather. The outer bark is then thrown off and a patch is formed, exposing the inner tissue

coated with a black crust, covering up the dried fibrous tissue below. This black crust is composed of the dead plant tissues coloured by the mycelium of a *Diplodia*. The disease is usually active only during the monsoon months, but may then develop with such rapidity as to make considerable progress before the gardener is aware of its presence. It is found chiefly at the base of the trees near the ground-level, but in rare cases it may also occur on the trunk higher up. The disease is most common on trees two or three years old and is rare on young ones. If the attack is very late in the rainy season the trees recover soon; the diseased patch is healed up and the bark only is cast off. Even in extremely severe attacks the tree is not killed rapidly. The effect is often confined for a long time to lessening the yield and size of the fruits. During stormy weather many trees fall over, breaking away at the point of attack. Cultures taken from the coal black crust commonly found in all diseased patches gave almost invariably a fungus belonging to the genus *Diplodia*, which has been identified with some doubt as *Diplodia Papayæ* Thuem[1]. For some time this fungus was supposed to be the causative organism. Inoculation experiments, however, did not produce the disease artificially under any circumstances.

In 1914, a *Pythium* belonging to the *gracile* group was isolated from the diseased papaya trees, and inoculations with this species did not yield any results. The inoculations were done in the cold weather, and the failure of these may be explained, in the light of the present experiments, as being due to the low temperature and dry weather at the time.

Recently an old tree was found with the typical symptoms of the disease. Many saprophytic fungi and bacteria were found in the diseased patches. Sections from the portion between the healthy and diseased patches revealed the presence of the mycelium of a Phycomycetous fungus in the tissues, and the same kind of mycelium was found under the bark and throughout the diseased patch ramifying freely through the cells. In one place there was a good fluffy growth. The mycelium was hyaline, with thick, granular protoplasm, unseptate in the young hyphæ and irregularly septate in the older. Pure cultures from this mycelium grown on glucose agar proved it to be a species of *Pythium* belonging to the *gracile* group and quite identical with that found on tobacco and ginger. The mycelium in the diseased bark disappears very soon and it is very difficult to detect it in old diseased patches. This explains the failure to find it in the earlier investigations.

[1] Sydow, H. and P., and Butler, E. J. "Fungi Indiæ Orientales, Part V." *Ann. Mycol.*, XIV, 1916, p. 198.

The night after this tree was examined there was heavy rain, and the next morning there was copious growth of the fluffy mycelium on the cut portions of the diseased patches.

Inoculation Experiments.

Tobacco.

The inoculations with the strain isolated from tobacco were successful only under moist conditions. In those cases where the plants were not covered with bell jars they failed. The inoculated portion of the leaf becomes soft and pale in colour within 24 hours, and the chlorophyll is destroyed. The softening gradually extends to the whole leaf, without being limited by the veins, and leads to total dissolution. Infections on the stem and the growing point produce the same results. In Plate III is a plant drawn on the third day after inoculation. The softening of the infected part is gradually extending to the healthier portions, and the pale-brown, small leaf sticking to the side of the pot shows the wet rot induced as the result of infection from material that ran down off the inoculated leaf.

The mycelium enters through any part of the epidermis and branches freely in the tissues. The hyphæ become constricted before piercing the cell wall. Sporangia are produced only when the infected leaf is floated on water. Irregular swellings on the hyphæ are quite common. Oospores are formed both intra- and extra- matrically, the former in larger numbers. Inoculations with this strain on ginger, castor, chilli, papaya, and potato were successful.

TABLE I.

Inoculations with strain isolated from tobacco.

Date	Plant inoculated	Treatment	Place of inoculation	Nature of inoculation	Result	REMARKS
16-9-16	4 tobacco seedlings.	Unwounded and covered with bell jars.	Leaves	Mycelium	3 + 1 −	
,,	2 tobacco leaves.	Do.	1 on upper surface. 1 on under surface.	Do.	2 +	
,,	Control	Do.	....	....	..	
19-9-16	1 tobacco plant.	Do.	Growing point.	Zoospores in water.	—	Failure perhaps due to drop running off the hairs.

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TABLE I—*concld.*

Date	Plant inoculated	Treatment	Place of inoculation	Nature of inoculation	Result	REMARKS
19-9-16	1 papaya plant.	Unwounded and covered with bell jars.	Growing point.	Zoospores in water.	+	
„	1 castor plant.	Do.	Do.	Do.	+	
„	Controls	Do.	....	....	...	
19-12-16	3 tobacco plants.	Do.	Leaves	Do.	3 –	Failure probably due to low temperature.
18-8-17	1 tobacco plant.	Do.	Growing point.	Mycelium	+	
„	1 ginger plant.	Do.	Do.	Do.	+	
„	1 papaya plant.	Do.	Do.	Do.	+	
„	1 chilli plant.	Do.	Do.	Do.	+	
„	1 castor plant.	Do.	Do.	Do.	+	
„	Sprouting potato tubers.	Do.	Young sprouts.	Do.	—	
„	Controls	....	....	..	..	
20-8-17	2 ginger plants.	Do.	Towarsd base.	Mycelium	2 +	
„	Potato tubers.	Do.	Young sprouts.	Do.	—	
27-8-17	2 tobacco plants.	Do.	Different places.	Mycelium	2 +	
„	2 chilli plants.	Do.	Do.	Do.	2 +	
„	2 castor plants.	Do.	Do.	Do.	2 +	
„	2 papaya plants.	Do.	Do.	Do.	2 +	
„	Controls	..	....	....	..	
22-9-17	3 papaya plants.	Block removed aseptically and culture inserted. Closed with moist cotton wool.	Base of stem.	Do.	3 +	Weather very damp with drizzling rain at times.

GINGER.

Inoculations with the strain from ginger were carried out on the same host on both wounded and unwounded plants. The results were the same in both cases, except that the action of the fungus was very rapid in wounded plants. The yellowish discolouration of the leaves, the dying of the top shoots, and softening of the collar were quite characteristic. The effect of the infection is seen after about 48 hours.

The hyphæ enter the host through the stomata or any epidermal cell, and swell a little before penetrating (Pl. VI, fig. 4) and also before passing through the cell walls of the internal tissues (Pl. VI, fig. 3). Inoculations with this strain on tobacco and the other plants mentioned above gave successful results.

TABLE II.

Inoculations with strain isolated from ginger.

Date	Plant inoculated	Treatment	Place of inoculation	Nature of inoculation	Results	REMARKS
21-11-16	2 ginger rhizomes.	Unwounded and covered with bell jars.	Rhizome	Mycelium	2 +	
,,	1 control	....	....	....	..	
9-6-17	1 ginger plant.	Unwounded and covered with bell jars.	Rhizome	Mycelium	+	
,,	1 Do.	Do.	Leaf-sheath	Do.	+	
,,	1 control	Do.	....	....	..	
12-6-17	2 ginger plants.	Unwounded and not covered with bell jars.	Leaf-sheath	Mycelium	2 −	Dry weather.
2-7-17	3 Do.	Do.	Do.	Do.	3 −	Do.
9-7-17	2 Do.	Do.	Do.	Do.	2 +	Weather damp after commencement of monsoon.
,,	1 Do.	Wounded and not covered.	Do.	Do.	+	
,,	1 control	Do.	....	....	..	
14-7-17	1 ginger plant.	Wounded and covered.	Rhizome	Mycelium	+	
,,	1 control	Do.	....	....	..	

TABLE II—*contd.*

Date	Plant inoculated	Treatment	Place of inoculation	Nature of inoculation	Result	REMARKS
28-7-17	1 ginger plant.	Wounded and covered.	Collar	Mycelium	+	
,,	1 Do.	Unwounded and covered.	Do.	Do.	+	
,,	1 Do.	Wounded and covered.	Rhizome	Do.	+	
,,	1 Do.	Unwounded and covered.	Do.	Do.	+	
,,	1 control	Wounded and covered.	....	....	..	
7-8-17	1 tobacco plant.	Unwounded and covered.	Leaves	Mycelium	+	
,,	1 castor plant.	Do.	Do.	....	+	
,,	1 papaya plant.	Do.	Do.	....	+	
,,	1 chilli plant.	Do.	Do.	....	+	
,,	4 controls.	Do.	....	....	..	
20-8-17	2 ginger plants.	Unwounded and covered with bell jars.	Leaf-sheath	Mycelium	2 +	
,,	Potato tubers.	Do.	....	Do.	—	
25-8-17	Potato boiled.	Covered with bell jars.	Unwounded surface.	Do.	..	Superficial growth only.
,,	Potato cylinder cut with borer.	Do.	Wounded surface.	Do.	+	
,,	Potato starch exposed by tangential cut.	Do.	Do.	Do.	+	
,,	Whole tubers.	Unwounded	....	Do.	—	
4-9-17	2 young potato plants.	Unwounded and covered.	Young shoot	Do.	2 +	
,,	1 control	Do.	....	....	..	

TABLE II—*concld.*

Date	Plant inoculated	Treatment	Place of inoculation	Nature of inoculation	Results	REMARKS
4-9-17	1 tobacco plant.	Unwounded and covered.	Young shoot	Mycelium	+	
,,	1 control	Do.	....	....	..	
12-9-17	1 papaya plant.	Do.	Petioles and leaves.	Mycelium	+	
,,	1 Do.	Do.	Collar and stem.	Do.	+	
,,	1 control	Do.	....	....	..	
,,	1 potato plant.	Do.	Leafy shoots.	Mycelium	+	
,,	1 control	Do.	....	....	..	
,,	2 clumps of ginger plants in the field.	Root system exposed and culture placed touching one of the roots and covered with soil.	Roots	Mycelium	—	
17-9-17	1 papaya plant.	Block removed aseptically and culture inserted. Closed with moist cotton wool.	Base of stem.	Do.	+	
,,	Same plant as last.	Unwounded. Culture placed on the surface on a different side and covered with moist cotton wool.	Do.	Do.	—	
22-9-17	2 papaya plants.	Do.	Collar	Do.	1 + 1 —	Weather very damp with drizzling rain at times.

PAPAYA.

Inoculations with the strain isolated from this host were quite successful on mature papaya trees, both wounded and unwounded. The wound inoculations were done in the following way :—A piece of the stem was removed under sterile conditions, and part of a culture of the fungus was placed in the cavity. After replacing the piece, the place was covered with a moist pad of

cotton wool. After 48 hours the effect of the fungus was seen. The wetting and softening of the tissues round the seat of inoculation and the exudation of the latex later on were quite characteristic. Penetration of the hyphæ takes place through any part of the plant. The mycelium was seen in the wood tissues and pith. The inner tissues became discoloured brown, and soft. A moist atmosphere greatly helps the spread of the fungus.

TABLE III.

Inoculations with strain isolated from papaya.

Date	Plant inoculated	Treatment	Place of inoculation	Nature of inoculation	Results	REMARKS
15-9-17	1 young papaya plant.	Unwounded and covered.	Collar	Mycelium	....	Superficial growth only.
,,	1 Do.	Wounded and covered.	Do.	Do.	+	
,,	1 control	Unwounded and covered.	....	....	..	
17-9-17	1 papaya plant.	Block removed aseptically and culture inserted. Closed with moist cotton wool.	Base of stem.	Mycelium	+	
,,	Same plant as last.	Unwounded. Culture placed on the surface on a different side and covered with moist cotton wool.	Do.	Do.	—	
22-9-17	3 large papaya plants.	Block removed aseptically and culture inserted. Covered with moist cotton wool.	Do.	Do.	3 +	Weather very damp with drizzling rain at times.
,,	2 Do.	Unwounded. Culture placed on the surface and covered with moist cotton wool.	Collar	Do.	2 +	Do.

Morphology of the Fungus.

The mycelium is composed of much branched hyphæ, sometimes showing false dichotomy, very variable in breadth from 3 to 8μ. Septation occurs very irregularly in old cultures. Irregular swellings on the hyphæ were quite common, when grown on plant tissues or in water culture. In glucose agar the hyphæ are not very broad, and in old cultures they are often septate. In maize and wheat meal the growth of the mycelium is luxuriant and the hyphæ uniform in breadth. In French bean agar the growth of the mycelium is not very luxuriant. On boiled ants the mycelium is very rich in protoplasm and the hyphæ broad. The formation of the sporangia is the same as described in *Pythium gracile*.[1] The sporangial stalk is not cut off by a septum from the parent hypha, but in badly nourished cultures a septum may occur at the base (Pl. V, fig. 6). The irregular swellings on the hyphæ serve as reservoirs of protoplasm, and under favourable conditions sporangia may develop from them. It is not uncommon to find empty cells at the base of the sporangial hyphæ. Sporangia have not been observed on solid media. The development of sporangia and oogonia follows no regular sequence. When cultures are kept in a cool incubator at 21°C., oospores appear first and later on sporangia. At 30°C. sporangia appear first.

The zoospores are from a few to 35 or more in number in each sporangium. They are bi-ciliate, bean-shaped, slightly depressed at the hilum where the two long cilia are attached, and measure when moving 8 to 12μ, 6 to 8μ in diameter, and when they come to rest 7 to 11μ. They germinate by one or more tubes, which on growing sometimes become septate. No special effect was seen on the discharge of zoospores as a result of lowering the temperature except the delayed formation of sporangia.

The oogonia are formed generally on short lateral stalks but sometimes are intercalar. They are also formed on the bud-like growths developed in the normal mycelium. They are spherical or sometimes slightly longer than broad, thin-walled, hyaline, and measure 18·7 to 33μ in diameter.

The antheridia may be terminal, or intercalar, or hypogynal. There is generally one antheridium for each oogonium but in rare cases two may be present. The antheridium generally rises from a different branch from that which carries the oogonium but in rare cases from the same branch. At times two antheridia are formed side by side on the same hypha intercalarly, and fertilize different oogonia. The terminal antheridia are club-shaped with a

[1] Butler. Loc. cit., p. 68, Pl. I, fig. 6.

pointed beak. The intercalar ones are knob-shaped and pointed. The oospores are round, smooth, hyaline, thick-walled and measure 13·5 to 25·3μ in diameter. They lie loose in the oogonia and germinate by a germ-tube (Pl. V, fig. 6).

The fertilization is the same as described by Ward.[1]

Systematic Position.

None of the species described under the *gracile* group comes very near to the present one, except the species studied by Butler and Ward[2] and provisionally put under *Pythium gracile* Schenk. However, this species differs in not being an algal parasite. Several inoculations on *Spirogyra* and *Cladophora* gave negative results.

Date	Plant inoculated	Treatment	Nature of inoculum	Result	REMARKS
18–1–18	Spirogyra sp.	Floated in a basin of tap water.	Pythium from tobacco	..	
,,	Do.	Do.	Pythium from papaya	..	
,,	Do.	Do.	Pythium from ginger from Surat.	..	
,,	Do. (control).	Do.	....	..	
,,	Do. (control).	Floated in a basin of river water	Boiled ants floated in the water to isolate any Pythium already present.		
28–1–18	Do.	Floated in a basin of tap water.	Pythium from papaya	..	
16–4–18	Do.	Do.	Pythium cultures from tobacco, papaya, ginger, mixed together.		
,,	Cladophora	Do.	Do.	..	
23–4–18	Spirogyra sp.	Floated in a basin of river water.	Do,		

From *Pythium monospermum* Prings. (*P. gracile* de Bary, *P. complens* Fischer), it differs sharply in the oospore lying quite loose in the oogonium (which may be twice the diameter of the oogonium of *P. monospermum*), and in the antheridia and oogonia usually arising from different branches and not

[1] Ward, H. M. "Observations on the genus *Pythium* (Prings.)." *Quarterly Journal of Microscopical Science*, n. s., XXIII, 1883.

[2] Ibid.

from the same as is common in the latter. I had *Pythium monospermum* Prings. under observation along with the present one. From *Pythium Indigoferæ* Butl. it differs equally in the characters of the sexual organs. A new name is therefore proposed for the parasite here studied :—*Pythium Butleri* n. sp. (After Dr. Butler, Imperial Mycologist, who first studied the disease on ginger.)

PYTHIUM BUTLERI, n. sp.

Mycelium composed of much branched hyphæ, sometimes showing false dichotomy, the main strands being 3 to 8μ broad and the lateral ramifications thinner. Irregular swellings quite common on the mycelium, which is septate in old stages. Sporangia lateral, elongated, slightly swollen at the tip. Zoospores few to 35 in number, bean-shaped, bi-ciliate, measuring when moving 8 to 12μ, 6 to 8μ in diameter, and after coming to rest 7 to 11μ. Oogonia lateral or intercalar, spherical or subspherical, thin-walled, and measuring 18 to 33 (average 26μ). Antheridia terminal or intercalar (when they are usually on a different hypha from that bearing the oogonium) or hypogynal (when they are on the same hypha as the oogonium), knob-shaped. Oospores, round, smooth, hyaline or light yellowish when fully mature, thick-walled, never filling the oogonium completely, 13·5 to 25·3μ in diameter (average 21μ). Oospores germinate by a germ tube, not by zoospores. Parasitic on *Nicotiana Tabacum, Zingiber officinale, Carica Papaya, Capsicum annuum*, and capable of attacking, when artificially inoculated, *Solanum tuberosum* and *Ricinus communis*.

Remedial Measures.

GINGER.

McRae[1] has given detailed information on the lines of treatment against this disease at Rangpur. The propagation of the disease is chiefly through the use of unhealthy rhizomes for planting, and in rare cases through soil where there is much water-logging. Some seed rhizomes were got from Rangpur, and planted near a crop of local ginger. The Rangpur variety developed the disease and the local one was free. Both had the same treatment. Since the local variety was free, it is evident that the seed rhizomes of the other variety were diseased before planting. So far the disease has been recorded only from Surat (Bombay) and Rangpur (Eastern Bengal). McRae estimated the loss in low lands from 10 to 15 per cent. as

[1] McRae, W. Loc. cit.

against a loss of 5 to 6 per cent. in dry lands. In bad years the whole crop may be destroyed. Butler estimated the loss in a single village near Surat in 1904 at Rs. 10,000. The disease is stated by McRae to be kept in check by adopting the following recommendations :—Burning of all diseased plants, rotation of crops, sowing of healthy seeds, good drainage, and clean cultivation. Some experiments were carried out on the Rangpur Farm[1] to check the disease on these lines and have been successful.

PAPAYA.

Much damage is done in wet seasons. The affected part of the tree should be cut off clean as soon as observed, and the cut parts should be bathed with an antiseptic solution. Sanitary fluid or crude carbolic acid mixed with equal quantity of water and applied with a brush has been found to be very successful. Coal tar can also be applied.

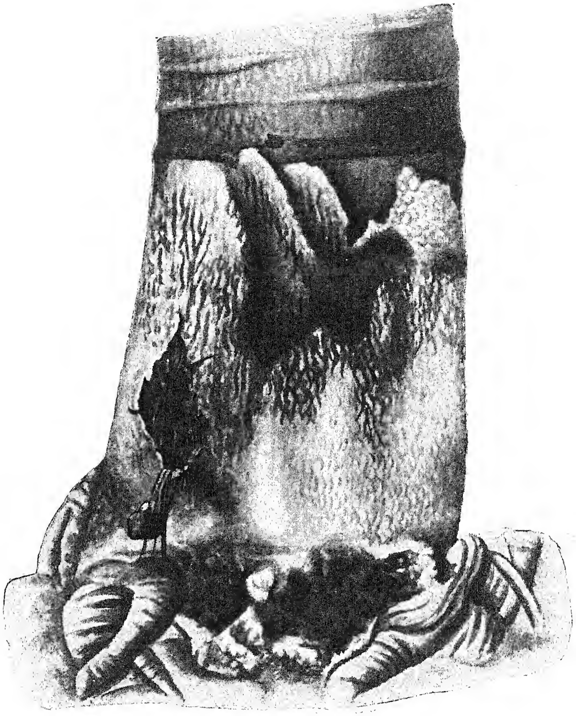
DAMPING OFF OF TOBACCO AND CHILLIES.

Treatment of seed beds with chemicals was not successful. Sterilizing the soil by burning dry grasses on the seed beds prevents the disease.

Note.—After this paper was sent to the press, cross inoculations with papaya strain of the fungus were carried out on ginger, tobacco, chilli and castor plants. All the inoculations were successful. It is quite clear from this that there is no specialization of parasitism among the different strains. [L.S.S.]

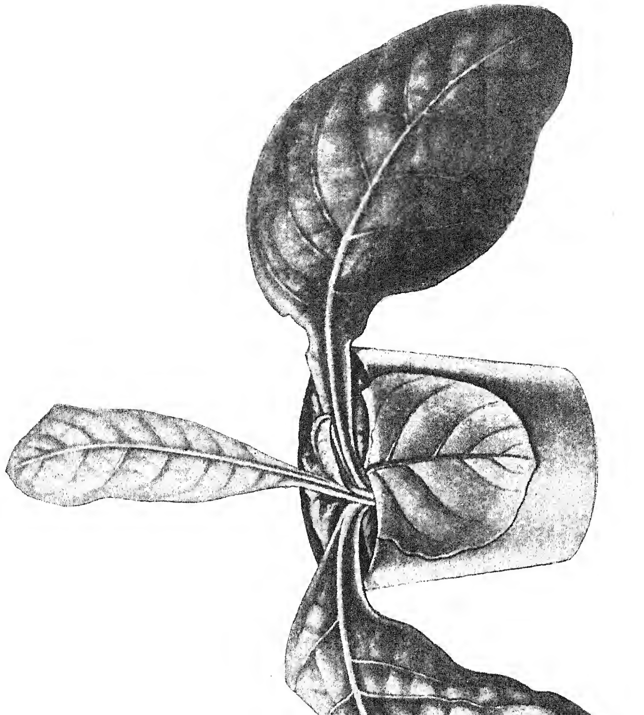
[1] "Annual Report of the Agric. Stations in Eastern Bengal and Assam for the year ending 30th June, 1908," p. 30.

Plate II is a reprint of one used to illustrate McRae's paper referred to in the text.

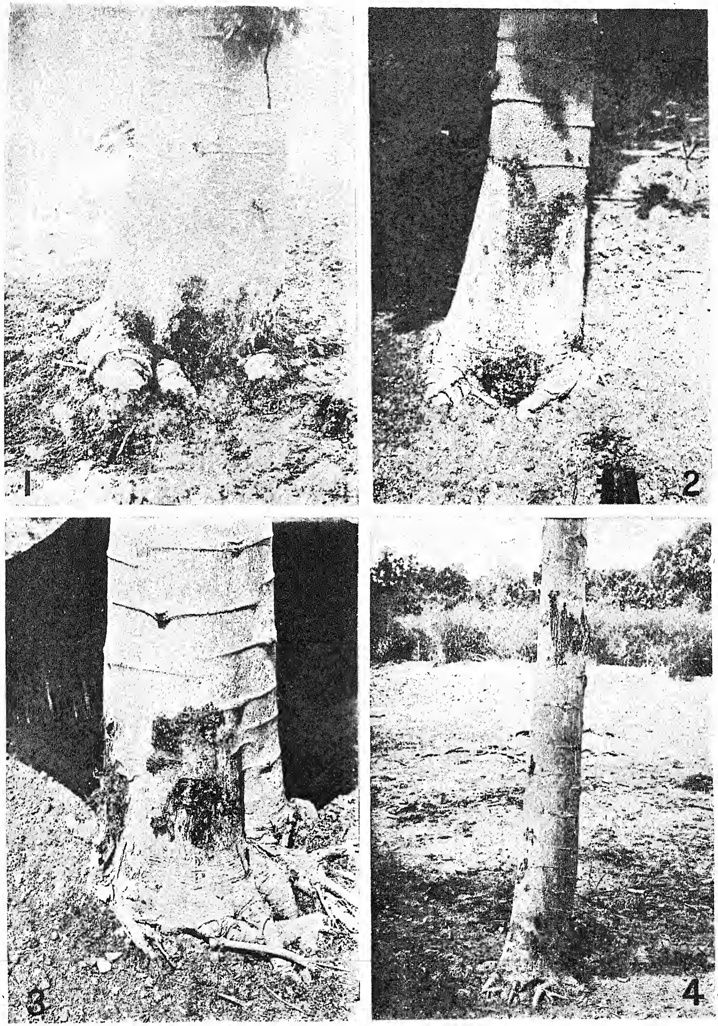


"Foot rot" at the base of a Papaya tree ($\frac{1}{4}$ Natural size).

Diseased and healthy Ginger plants.



Soft rot induced in the leaves of Tobacco. (Natural size).



"Foot rot" on Papaya trees.

EXPLANATION OF PLATE V.

Fig. 1. Branching of mycelium from culture grown on papaya fruits. 110 ×.
" 2. Branching of mycelium from culture grown on boiled ants. 110 ×.
" 3. Same a little more enlarged. 270 ×.
" 4. Young sporangial hypha. 110 ×.
" 5. Buds on hypha. 500 ×.
" 6. Sporangial stalk cut off by a septum in an old culture. 500 ×.
" 7. Zoospore formation. 500 ×.
" 8. (*a*) Zoospore. 750 ×.
(*b-h*) Zoospores germinating—different stages. 500 ×.
Figs. 9 to 11. Oospore formation from the papaya strain. 750 ×.
Fig. 12. Two intercalar antheridia fertilizing different oogonia. 750 ×.
" 13. Antheridium and oogonium arising from the same branch. 750 ×.
" 14. Ripe oospore. 750 ×.

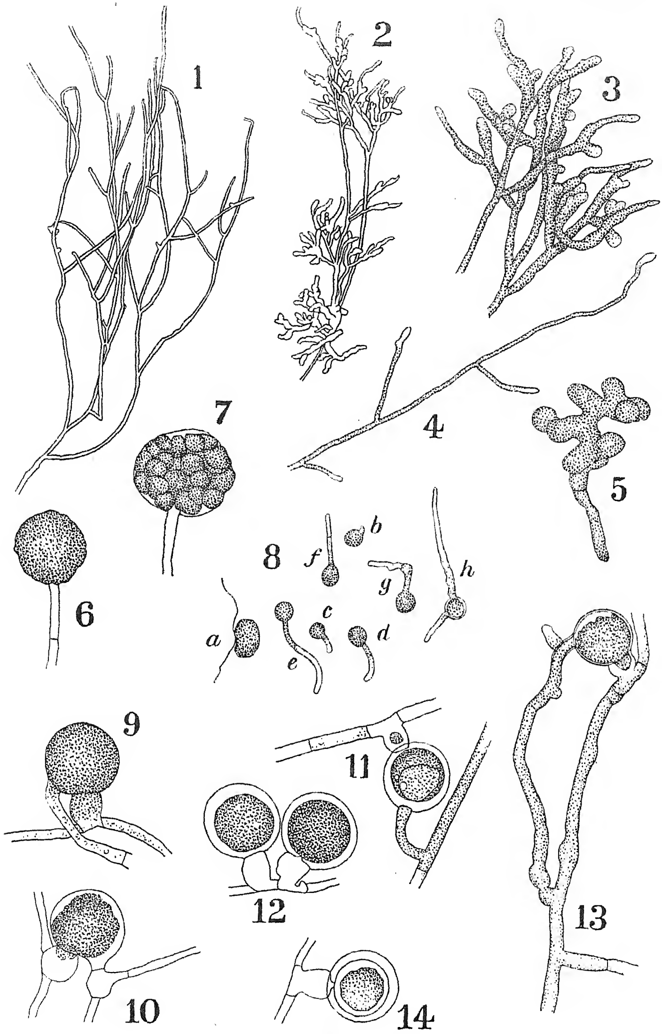

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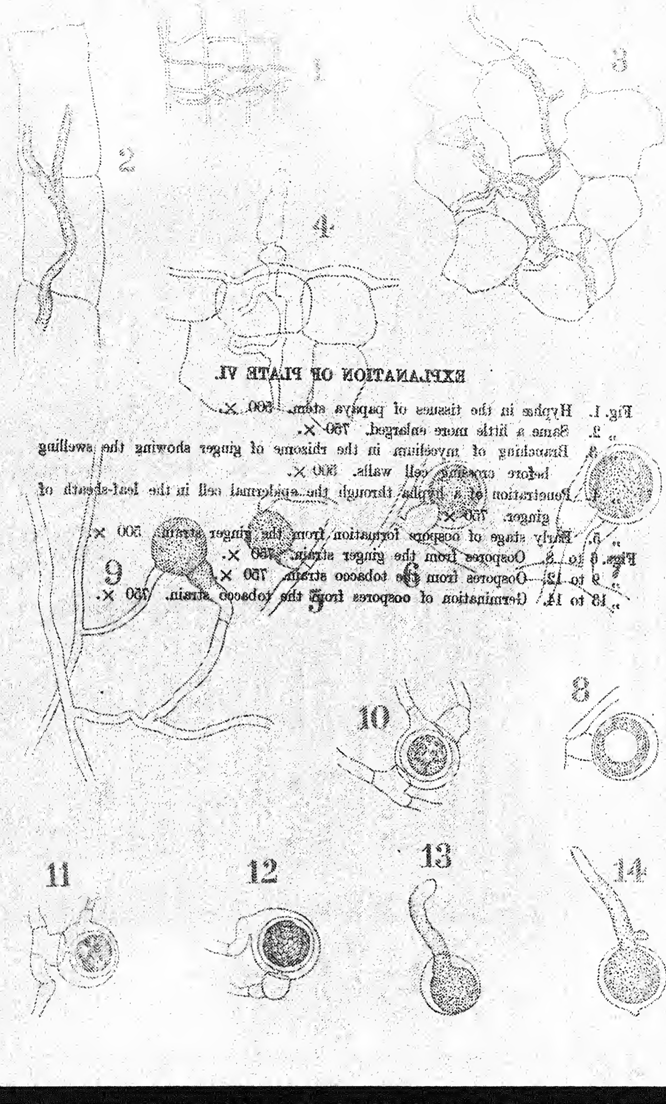
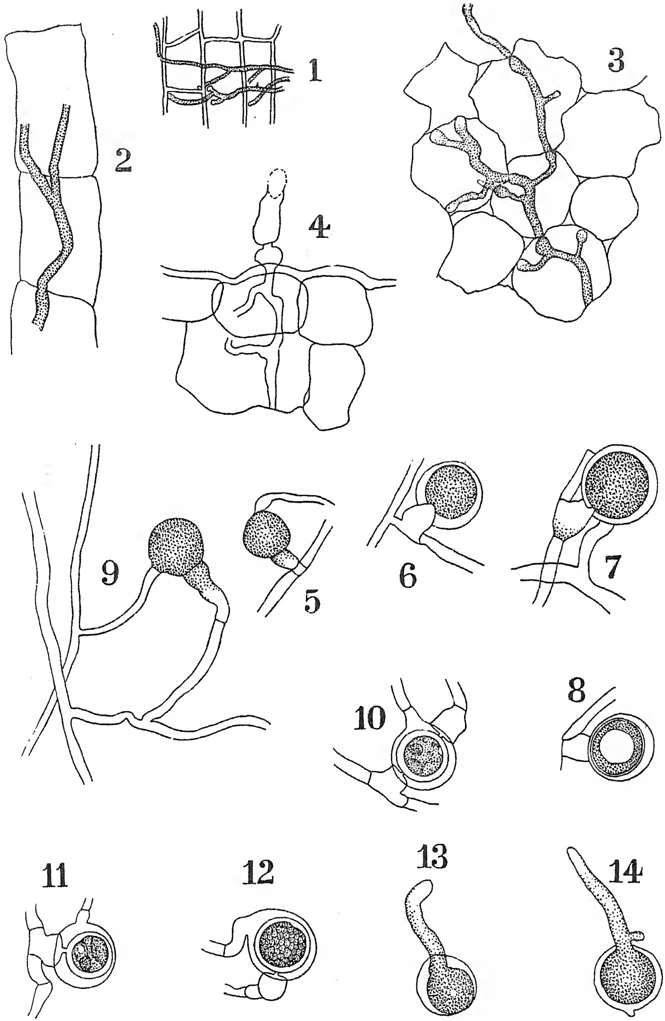
PLATE VI.



EXPLANATION OF PLATE VI.

Fig. 1. Hyphæ in the tissues of papaya stem. 500 ×.
„ 2. Same a little more enlarged. 750 ×.
„ 3. Branching of mycelium in the rhizome of ginger showing the swelling before crossing cell walls. 500 ×.
„ 4. Penetration of a hypha through the epidermal cell in the leaf-sheath of ginger. 750 ×.
„ 5. Early stage of oospore formation from the ginger strain. 500 ×.
Figs. 6 to 8. Oospores from the ginger strain. 750 ×.
„ 9 to 12. Oospores from the tobacco strain. 750 ×.
„ 13 to 14. Germination of oospores from the tobacco strain. 750 ×.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CONTENTS

STUDIES IN THE POLLINATION OF INDIAN CROPS. I.

BY

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I. INTRODUCTION.

THE methods of pollination and the occurrence of cross-fertilization are matters of the first importance in the improvement of crops in India. On accurate information on these subjects depends the choice of the methods of improvement to be adopted, the testing of the new varieties obtained as well as the growth and distribution of seed to cultivators. The earlier results obtained in this direction at Pusa were published towards the end of 1910 in a paper entitled *The economic significance of natural cross-fertilization in India*[1] which dealt more with the occurrence of natural crossing in the field than with the detailed study of the flower and of its pollination. Since that time, the work has been continued in much greater detail and a number of other crops have been investigated. The facts connected with the flowering, pollination and fertilization of gram (*Cicer arietinum* L.), safflower (*Carthamus tinctorius* L.), and Indian mustard (*Brassica juncea* H. f. & T.), were incorporated in papers dealing with the general botany of these crops published in

[1] *Mem. of the Dept. of Agr. in India* (*Botanical Series*), vol. III, 1910, p. 281

1915.[1] Some of the information relating to Java indigo was published in 1916.[2] The present paper deals with the results obtained, up to the end of the *rabi* harvest of 1919, on the following crops:—San-hemp (*Crotalaria juncea* L.), pigeon pea (*Cajanus indicus* L.), Java indigo (*Indigofera arrecta* Hochst.), Sumatrana indigo (*Indigofera Sumatrana* Gaertn.), linseed (*Linum usitatissimum* L.), *taramira* (*Eruca sativa* Lam.), *til* (*Sesamum indicum* L.), *niger* (*Guizotia abyssinica* Cass.), jute (*Corchorus capsularis* L., and *C. olitorius* L.) and roselle (*Hibiscus Sabdariffa* L.).

The bearing of pollination studies on such subjects as the methods of improvement of crops, the introduction of exotics, the maintenance of types and the distribution of pure seed to cultivators, has already been discussed in two papers[3] (published in 1910 and 1912) largely from the point of view of the application or otherwise of the methods of pure line selection. Some of the results described in the present paper, for example, those dealing with the pigeon pea, indigo, and san-hemp, bring out other aspects of plant improvement which are not without interest at the present time.

In the pigeon pea, a crop widely grown and of great value in the rural economy of the country, yield is of far greater importance than quality. The problem before the breeder is to secure the heaviest crop possible. In carrying this out, the facts dealing with pollination and fertilization show that other factors, besides potential yielding power, are involved. Fertilization depends on atmospheric conditions and practically no setting takes place during damp, dull weather although self-pollinated flowers may be produced in profusion. This adverse factor can be avoided by increasing the range of the flowering period. This can be achieved most easily by the growth of a mixture of individuals differing considerably in time of flowering. In this way the risk is distributed and the yield is insured. This, however, involves the rejection of the method of pure line selection and the adoption in its place of mass selection in which crossing within certain limits is permitted.

In Java indigo the case is still more interesting. The crop consists of a mass of freely crossing heterozygotes with a wide range in general habit, root development, time of flowering and in the extent of leaf surface. Practically no setting takes place if insect visitors are excluded. The seed produced by artificial self-pollination is small in amount and gives rise to progeny of less

[1] *Mem. of the Dept. of Agr. in India (Botanical Series)*, vol. VII, nos. 6 & 7, 1915, pp. 213 & 237.

[2] *Bulletin No. 67, Agr. Research Inst. Pusa*, 1916, p. 23.

[3] *Mem. Dept. of Agr. in India (Botanical Series)*, vol. III, no. 6, 1910, and *Agr. Jour. of India*, vol. VII, 1912, p. 167.

vigour than that obtained when free flowering is permitted. These facts to all intents and purposes exclude methods of improvement based on the isolation of pure lines. There has been so much crossing in the past and the gametic constitution of each individual is so complex that many years' work would be necessary for the isolation of the unit species which underlie, as it were, the existing fabric of heterozygotes. Time is not the only factor involved in this unravelling. The crop is to some extent self-sterile and the plants raised from self-fertilized seed show, in a single generation, a considerable falling off in vigour. The isolation of pure lines in such a crop involves continuous self-fertilization for many years which would be certain to have its effect on the vigour of the culture. If the operation of this factor did not eliminate the selections altogether, it would be certain to lower their vitality to such an extent that the pure lines finally obtained would be worthless for any agricultural purpose. Methods of continuous mass selection, on the other hand, which were successfully adopted by the Dutch planters in Java when this crop was cultivated in that country, are far more promising. No attempt is made to prevent crossing but it is regulated and only permitted to occur between those individuals which are agriculturally desirable.

Cross-fertilization in the field is not the only way in which pure cultures can be contaminated. This can be brought about by the infection of the soil by self-sown seed of previous cultures of the same crop. The danger is specially important when hard seeds are produced and when the seeds possess the property of lying dormant in the soil in a viable condition for many years. One obvious method of avoiding the difficulty is the possession of a number of separate plots combined with a system of rotation. This suffices in all ordinary cases. In crops like roselle, Java indigo and Indian mustard, however, this is not sufficient. Dormant and hard seeds are brought up by the plough every year and self-sown seedlings of these crops have been known to appear in the plots of the Botanical Area at Pusa five years after the removal of the last culture. In addition to rotations and clean cultivation, two other methods are employed at Pusa to avoid contamination in such cases. After the removal of the culture, the plot is left uncultivated for a time so that the seeds left on the surface may dry thoroughly so as to increase their germination capacity. The land is then lightly cultivated after rain or irrigation when vast numbers of seedlings appear which are easily destroyed by a further cultivation. This process is repeated when possible. Afterwards the land is ploughed in the ordinary course. In this way, most of the seeds are destroyed and only a few are buried by the plough. In addition, such crops are always grown either in lines or transplanted from

seed boxes in lines at a definite distance between the plants. Provided all due care is taken and the cultures are kept under close observation, especially at the beginning, the danger of contamination through self-sown seed can be avoided altogether.

II. Some leguminous crops.

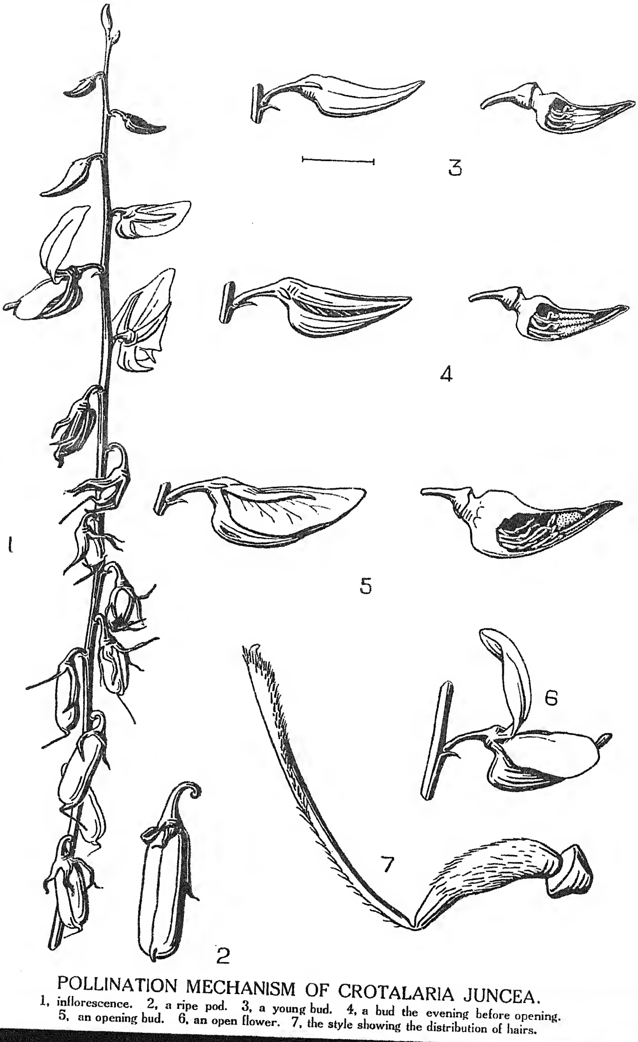
1. San-hemp.[1]

San-hemp (*Crotalaria juncea* L.) is widely cultivated all over India mainly for its fibre and as a green manure crop.

Flowering. The large conspicuous yellow flowers are borne on long terminal racemes, the first blossoms appearing when the plants have attained their full height (Plate I). The lowest flower of each inflorescence opens first and flowering proceeds regularly towards the growing point and is completed in the whole plant in about a month. The carina is very pointed, slightly twisted at the apex and closely shut. The stamens are diadelphous and unequal. The anthers of the shorter stamens are linear, of the longer ovate. Those buds which show slits in their calyces in the late afternoon with the yellow corolla showing through, open the following morning about 9 to 10 A.M. at which period the glands begin to secrete nectar freely. As a rule the flowers remain fully open for two days, partially closing at nightfall. Comparatively few of the flowers set seed under Pusa conditions.

Pollination. In the bud stage (Plate I) the two sets of anthers are in position at a considerable distance below the stigma. When slits appear in the calyx, dehiscence of the linear anthers begins and the filaments of the ovate set of anthers begin to increase in length and to press the liberated pollen towards the orifice of the carina. When the flower is fully open, the stigma (which is provided with a bunch of hairs round the stigmatic surface) lies towards the orifice of the keel and is free from the mass of pollen supported by the ovate anthers which have not yet burst. In addition to the bunch of hairs there is a line of hairs pointing upwards along the whole length of the style. These help to keep the pollen in position. When heavy insects like *Megachile anthracina* or *Xylocopa amethystina* alight on the wings and search for nectar, the piston mechanism is set in motion and first the stigma and then a pasty vermiculous mass of pollen are extruded and forced somewhat violently against the hairy abdomen of the insect. The flowers are also visited by *Megachile lanata* but this insect is too short for the stigma to strike its abdomen. It is however heavy enough to set the piston mechanism in motion and collects

[1] *Mem. Dept. of Agr. in India* (*Botanical Series*), III, 1910, p. 177; *Die Züchtung der landw Kulturpflanzen* Bd. V, 1912, s. 145.



POLLINATION MECHANISM OF CROTALARIA JUNCEA.

1, inflorescence. 2, a ripe pod. 3, a young bud. 4, a bud the evening before opening. 5, an opening bud. 6, an open flower. 7, the style showing the distribution of hairs.

pollen and in doing so is able to stimulate the stigmatic surface and to effect cross-pollination. The two small Indian bees, *Apis indica* and *A. florea*, visit the flowers for pollen left by the other insects but are not heavy enough to work the mechanism and therefore have no influence as pollinating agents. If the flowers are not visited by insects, the continued elongation of the filaments of the long stamens presses the pollen mass round the stigma. Both cross and self-pollination are therefore possible. The ovate anthers do not burst until their work of supporting the pollen mass in the carina is completed towards the end of the first day of opening or on the morning of the second. The arrangements for pollination therefore follow for the most part those described by H. Müller[1] in the case of *Lupinus luteus* L., but the piston mechanism is in *Crotalaria juncea* combined with the brush system of *Pisum sativum* L.

Fertilization. The arrangements at first sight suggest the possibility of self-pollination as well as cross-pollination but the former does not occur if the flowers are protected from insects. If flowering takes place in muslin cages, the pollen is liberated and forced all round the stigma in the usual manner but no subsequent setting takes place. The flowers last for four or five days and then gradually fade. If, however, a branch is led outside the net into the open air, setting takes place normally and pods and seeds form in the usual manner. These results suggest that the stigma must first be stimulated by contact with the insect before the pollen grains can germinate. To confirm this, some experiments were made in 1916 in which the stigmas were rubbed with rough cardboard before selfing. In all cases the experimental plants were covered with netting before flowering time and in two cases control inflorescences were allowed to flower freely outside. The results are given in the following table :—

Dates of rubbing and of self-pollination	No. of flowers treated	No. of pods produced	No. of pods which set seed	Total No. of seeds	
22nd October to 26th October	58	1	1	2	The free flowering branch formed 11 pods which gave 33 seeds.
22nd October to 26th October	65	15	13	73	The free flowering branch formed 13 pods which gave 38 seeds.
11th November to 17th November	103	49	40	..	No free flowering branch.

[1] H. Müller. *Fertilization of Flowers*, 1883, pp. 187 and 211.

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These results prove that in this species as in many others of this order, autogamy does not occur unless the stigmatic surface is first stimulated. One consequence, therefore, of insect visitation is self-pollination. Stimulation of the stigmatic surface does not appear necessary however for cross-pollination. In 1916, a number of flowers were artificially crossed without first of all rubbing the stigma. All formed pods and set seed. These results indicate that cross-pollination by means of insects is the first object and that only if this fails is seed formation provided for by self-pollination.

Natural cross-fertilization. All the facts point to the possibility of extensive natural crossing in this crop. That this is so was confirmed by an experiment carried out at Pusa with two cultures of very different habit which were grown side by side and allowed to flower freely for some years. The morphological differences of these cultures are summed up in the table :—

Local Pusa variety	Jubbulpore variety from the Central Provinces
1. *Seed.* Small, shiny, black.	Large, dull black or greyish.
2. *Seedlings.* Germination slow, small, with reddish downy cotyledonary leaves and stems.	Germination rapid. Seedlings large with green glabrous cotyledonary leaves and stems.
3. *Plants.* Short, late maturing, with many flowered spreading branches beginning at a point about four feet from the ground.	Tall, early maturing, with a few short sparsely flowered parallel branches beginning at a point about eight feet from the ground.

At first, the natural differences between these two kinds were maintained but they somewhat rapidly disappeared and in two or three years the cultures were indistinguishable. Crossing had evidently taken place in all directions and eliminated the well marked differences in habit.

This result led to a detailed examination of the local Bihar crop in order to determine its constitution. The greatest amount of variation was noted in the standard of which twelve distinct types could be distinguished, differing in the colouration of the veins, in the depth of yellow and in the amount and distribution of a reddish tinge existing with the yellow. Several colour factors therefore occur in the flower and there is little doubt that the crop contains numerous forms differing very slightly from one another.

Improvement. The fact that no setting takes place if the flowers are protected, that seed formation is dependent on insect visits and that extensive natural crossing takes place render the improvement of this crop a difficult matter. Variety trials, extending over several years, are only possible by

the use of fresh seed for each set of sowings. Seed distribution to be successful would involve the production of enormous volumes of seed and arrangements for complete substitution of the existing crop over a large area. Anything less than this would rapidly be destroyed by vicinism. It is doubtful whether the improvement possible would repay the cost and trouble involved.

2. Pigeon pea.

The pigeon pea (*Cajanus indicus* Spreng.) is widely cultivated in most parts of India. Two varieties are referred to in the Indian literature on this crop—(1) var. *florus,* known as *tur* (early maturing with a dwarf habit), found largely in the Central Provinces and in Central India, and (2) var. *bicolor*, known as *arhar* (late maturing with a tall habit), cultivated in the plains. The crop prefers a light, moist soil with good natural surface drainage. Its principal enemy is frost, a danger which limits its cultivation in the colder regions of North-West India. *Arhar* is perhaps the most valuable restorative crop grown in India. By means of its deep penetrating roots, the sub-soil is broken up and aerated while by the fall of its leaves and flowers a considerable amount of organic matter is added to the soil. For these reasons, the crops which follow *arhar* as a rule give yields above the average. The flowers are papilionaceous and are borne in loose corymbose racemes sometimes forming a terminal panicle. They open at any time of the day from 9 A.M. to 5 P.M. and remain open for about a day and a half.

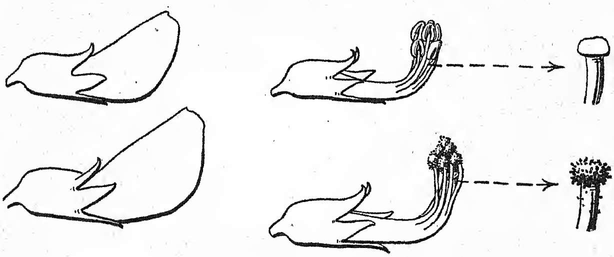


FIG. 1. Pollination of *Cajanus indicus* in the bud.

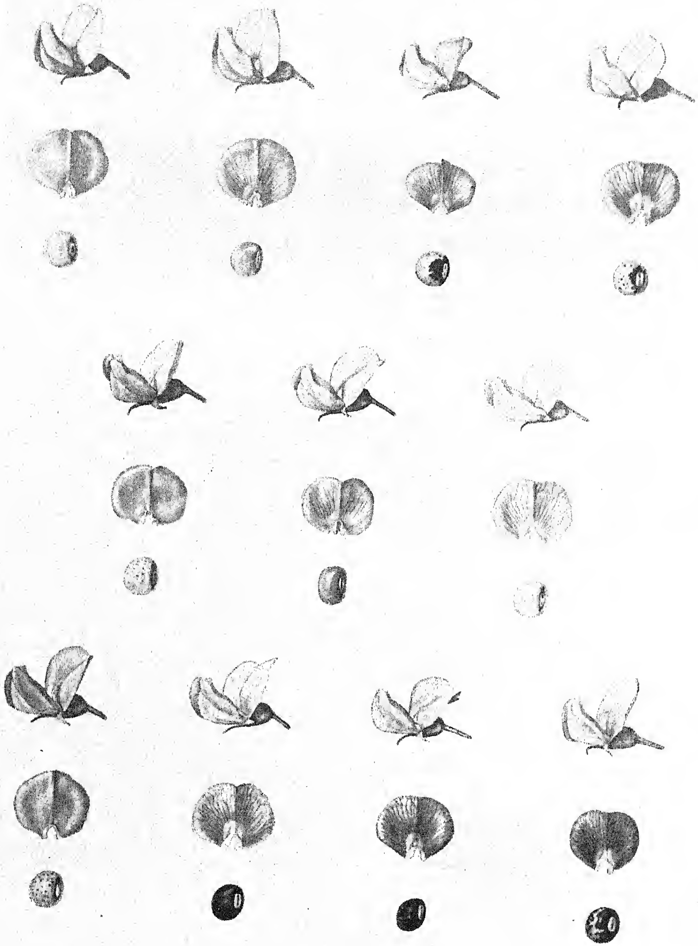
Pollination. In the bud stage, the anthers surround the stigma and burst the day before the flower opens and a dense mass of pollen is distributed all over the stigmatic surface (Fig. 1). In dry sunny weather, this pollen mass is partly removed by the action of wind and by the bees which visit the

flowers in large numbers. If, however, the weather is damp, the pollen masses decompose into a gelatinous substance, fertilization does not take place and the flowers fall.

Fertilization. This crop is characterized by the great extent of its flowering period and by the enormous number of flowers it produces. All are self-pollinated before the flowers open but the great majority fall without setting any seed. The expenditure of energy in flower formation is extraordinary. Setting depends on the humidity of the air. Dry bright days favour fertilization while dull damp weather causes the pollen grains to disintegrate and the flowers to fall without forming seed. Under dry bright conditions setting takes place freely under nets when insect visitors are excluded, thereby proving that self-fertilization readily takes place. The fact that the flowers are constantly visited by bees suggests that cross-fertilization is also possible.

Natural cross-fertilization. A considerable amount of work has been carried out at Pusa on the occurrence of natural cross-fertilization in this crop. In 1909, samples of *arhar* seed were collected from Bihar, the United Provinces, the Central Provinces and Bombay. The following year, 68 single plants were selected and the seed of each was sown separately. Of these, 61 gave rise to obviously mixed offspring while 7 (belonging to Bihar) appeared to breed true. In 1911, a further selection of 72 single plants was made of which 26 were obtained from cultivators' fields in the neighbourhood of Pusa. These were sown separately and definite splitting was observed in 65 of these cultures in the following respects—habit, time of flowering, colour of flowers (pale yellow, yellow, deep yellow, orange yellow, orange, reddish orange and all kinds of intermediate tints), colour and shape of the pods and seeds. In 1914, another set of 41 different plants was selected on the Dholi Estate. Twenty-three of these cultures did not breed true. The above results prove that natural crossing is common in the pigeon pea. As the self-pollinated flowers are largely visited by bees, it is probable that these insects are mainly involved.

To determine the precise extent of natural crossing, some observations were made in 1912-13 on a pure culture of *arhar* (characterized by pale yellow flowers and white seed) grown on a plot about half an acre in size next to a similar area of the ordinary local crop. The colour of the flowers and seeds of this pure culture made the detection of heterozygotes an easy matter. One hundred and forty single plants which were true to flower and seed colour were selected and sown separately the following year. Natural crossing was found to have occurred in 91 of the cultures (40 as regards flower colour and 41 as regards seed colour), that is, in 65 per cent. An exact count of the number



NATURAL CROSS-FERTILIZATION IN THE PIGEON PEA.

of crossed plants as regards flower colour was made in 40 of these cultures in each of which there was an average of sixty plants. Thirty cultures had only one stray plant each, seven had two plants, two had three plants and one had four plants—altogether 54 heterozygotes as regards flower colour among 2,400 plants, or 2·25 per cent. Through an oversight, similar counts as regards seed characters were not carried out. Grown in single lines next to next, the percentage of natural crossing is much larger. In an actual case it was found to be (as regards flower colour only) 578 in a total of 4,838 plants, or 12 per cent.

The characters which best lend themselves to the detection of heterozygotes and which show the kind of splitting which takes place in this crop are the general colour and markings of the standard, the colour of the pod and the characters of the seed coat. A number of careful observations have been made on these matters which are worthy of record.

As regards splitting in the general colour of the flower and in the markings of the back of the standard, the following three cases may be quoted :—

1. A parent plant with orange flowers (the back of the standard with many red lines and a diffused reddish colour) gave rise the next year to 64 plants which were grouped as follows (Plate II) :—

(*a*) *Flowers pale yellow.*

		Plants
Back of the standard	Without lines	2
	With a few red lines	4
	With red lines	2
	With many red lines	2

(*b*) *Flowers deep yellow.*

Back of the standard	Without lines	6
	With a few red lines	2
	With many red lines	4

(*c*) *Flowers orange.*

Back of the standard	Without lines	9
	With red lines	13
	With many red lines	12
	With many red lines and more diffused red colour	8

2. A parent plant with orange flowers (the back of the standard having red lines and a diffused red colour) gave rise the next year to 47 plants with yellow or orange flowers, differing however as regards the markings on the back of the standard as follows :—

	Plants
Uniformly deep red	24
Orange without red lines	4
Reddish orange without red lines	12
Yellow orange with red lines	7

3. A parent plant with yellow flowers (the back of the standard yellow with very faint red lines) gave rise the next year to 52 plants as follows :—

(*a*) Flowers orange, the back of the standard with red lines and diffused red colour ... 1 plant.

(*b*) Flowers yellow, the back of the standard without or with very faint red lines .. 25 plants.

(*c*) Flowers yellow, the back of the standard with many red lines but without any diffused red colour .. .. 26 plants.

The pods may be green or variously marked with red or black, the black markings being sometimes present to such an extent that the pod appears to be entirely black. The following three cases illustrate the splitting which occurs in the colour and markings of the pods :—

Parent	Progeny		Total number of plants
Pods with reddish lines	Black or reddish lines ..	30	42
	Nearly black	1	
	Green without lines ..	11	
Pods green without lines	Green without lines ..	14	52
	Nearly black	22	
	With black lines ..	16	
Pods with red lines ..	Green without lines ..	10	40
	With reddish black lines ..	29	
	Pods reddish black ..	1	

The most important seed characters are those of the seed coat. The ground colour may be white, grey, brown, reddish brown, purple, smoky or black. In general, there are, in addition to this ground colour, brown, black, violet or red spots or patches. When the ground colour is white or grey, two coloured spots occur one on either side of the hilum. In many cases, the

hilum is surrounded by a coloured ring. There appears to be no obvious connection between the colour of the seeds and the colour of the flowers (Plate II). Plants having similar flowers differ as regards the colour of the seeds, while similar seeds produce a wide range of colour in the flowers. The following three cases illustrate the kind of splitting met with as regards the colour and markings of the seed coat :—

Parent	Progeny		Total number of plants
Seeds whitish with a violet tinge and violet spots.	White to brown with or without a brownish ring round the hilum ..	20	60
	Light brown	3	
	Brown with a deep brown ring round the hilum or deep brown patches ..	3	
	Red	3	
	Smoky black	1	
	Black	3	
	Violet	1	
	White to brown with a violet ring round the hilum and violet patches and spots ..	26	
Seeds smoky black with black marks.	Violet black	1	44
	Yellowish brown ..	14	
	Smoky without any marks ..	10	
	Smoky with black marks ..	19	
Seeds reddish black.	Black	3	33
	Reddish black with black spots	3	
	Nearly black with patches ..	2	
	Smoky red	4	
	Dark red	5	
	Brown with black spots ..	3	
	Dark brown	3	
	Brownish red	3	
	Yellowish	7	

Improvement. Yield is of far greater importance than quality in the pigeon pea. Moreover, fertilization is dependent on the weather. To ensure the crop therefore a fairly wide range of forms as regards time of flowering is almost certain to give better results than a pure culture. Some experiments have been made on this point at Pusa. In 1911-12, one of the most promising of the pure lines, characterized by pure white seed and a pale yellow standard, was compared with the local mixed crop with the following results :—

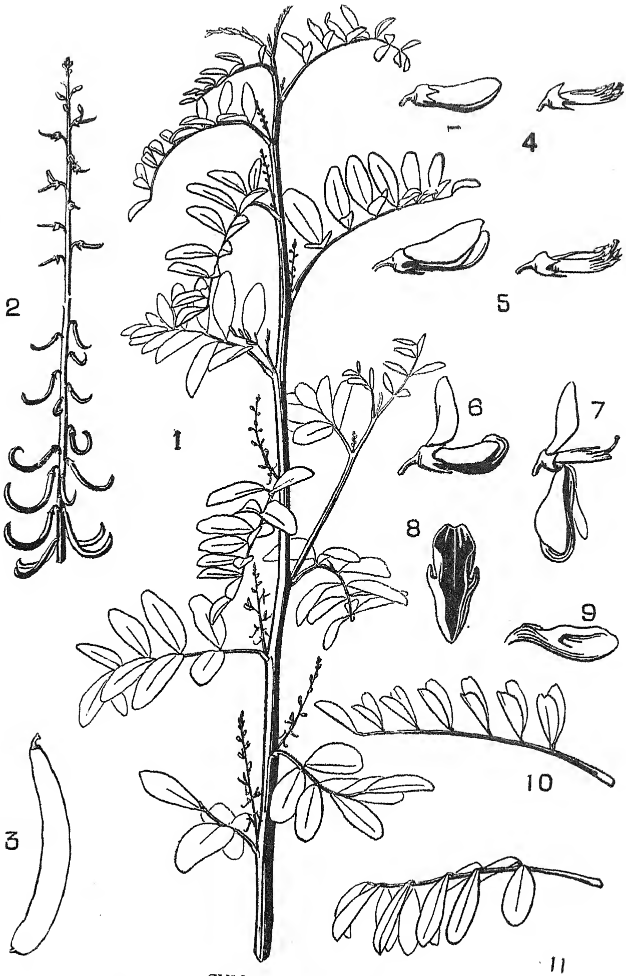
Variety	Area in acres	Actual outturn		Yield per acre	
		m.	s.	m.	s.
Pure line ..	0·5	5	6	10	12
Local crop ..	0·5	12	20	25	0

This result was not due to poor vegetative growth or lack of flowering on the part of the pure line but entirely to the better setting of the local crop, the flowering period of which was much greater than that of the pure culture. In the selection, out of a total of 4,838 plants, 578 plants split as regards flower colour. These two sets were threshed separately and the total weight of seed was determined. The results are given in the following table :—

Variety		No. of plants	Outturn in seers	Outturn per plant in seers
Selection	Homozygotes ..	4260	150	0·035
	Heterozygotes ..	578	56	0·097
Local crop ..	..	4784	500	0·105

The heterozygotes gave nearly three times the yield of the homozygotes. The next year, a comparison was made between the product of these heterozygotes and the local crop. The results were as follows :—

Variety	Area in acres	Actual outturn		Outturn per acre	
		m.	s.	m.	s.
Heterozygotes	0·58	6	18	11	5
Local crop	0·53	8	30	16	20



SUMATRANA INDIGO.

1, a flowering branch. 2, an inflorescence. 3, a ripe pod. 4, a bud. 5, an opening bud. 6, a flower just before an insect visit. 7, a sprung flower 8. the carina seen from above. 9, side view of the carina. 10, the position of the leaflets at midday. 11, the night position.

These results of course do not prove that pure line selection in this crop will never, under any circumstances, lead to improvement. They indicate however that the method will be attended with very considerable difficulties. Continuous mass selection by the elimination of unthrifty plants will probably give the best results.

3. Java Indigo.

The details relating to the flowering, pollination and to the occurrence of natural cross-fertilization in Java indigo (*Indigofera arrecta* Hochst.) were described and figured in 1915 in Bulletin No. 51 of the Agricultural Research Institute, Pusa. The bearing of these facts on the improvement of this crop was dealt with in considerable detail in Bulletin No. 67 published in 1916. Very little self-fertilization takes place in the case of protected flowers, the visits of bees being necessary for seed formation. The crop is composed of a mass of heterozygotes, differing widely in habit, time of flowering, root range and amount of leaf surface. There is evidence for believing that self-sterility occurs to some extent as there is a great falling off in vigour observable in the plants raised from self-fertilized seed. These circumstances and the ease with which the land becomes contaminated with the seed of previous cultures will render the improvement of Java indigo by the methods of pure line selection a time-consuming and very difficult undertaking. As is well known, this crop produces hard seeds in abundance and at harvest time there is a considerable amount of loss through the explosion of the pods. These hard seeds germinate naturally a few at a time during the second half of the monsoon and readily contaminate any culture sown on the same land unless special precautions are taken.

4. Sumatrana Indigo.

The structure of the flower and the arrangements for pollination in the case of Sumatrana indigo (*Indigofera Sumatrana* Gaertn.) closely follow those of Java indigo. The anthers burst in the bud just before the flower opens in the early morning. The flowers are visited during the morning by bees (*Apis florea* and *A. indica*), and the well known phenomenon occurs of the upwards discharge of pollen brought about by the explosion of the flower (Plate III). On November 11th, 1915, observations beginning at 7-15 A.M. were made on two branches to determine the number of flowers which opened and which were sprung during the course of a day. By 9 A.M., 13 flowers were open of which 7 were sprung. At 5 P.M., the same day, a total of 32

flowers had opened since 7-15 A.M. of which 31 had been sprung. In the two succeeding days, 77 more flowers opened, all of which were sprung.

Practically no setting takes place under nets but seed is produced under these conditions if the flowers are artificially made to explode. The amount of setting however is less than that obtained in the case of free-flowering plants visited by bees.

Attempts to cross Java and Sumatrana indigo at Pusa have so far failed. On several occasions, plots of these two crops have been allowed to flower side by side in October and November but no natural crosses have been observed in succeeding generations.

III. Oil seed crops.

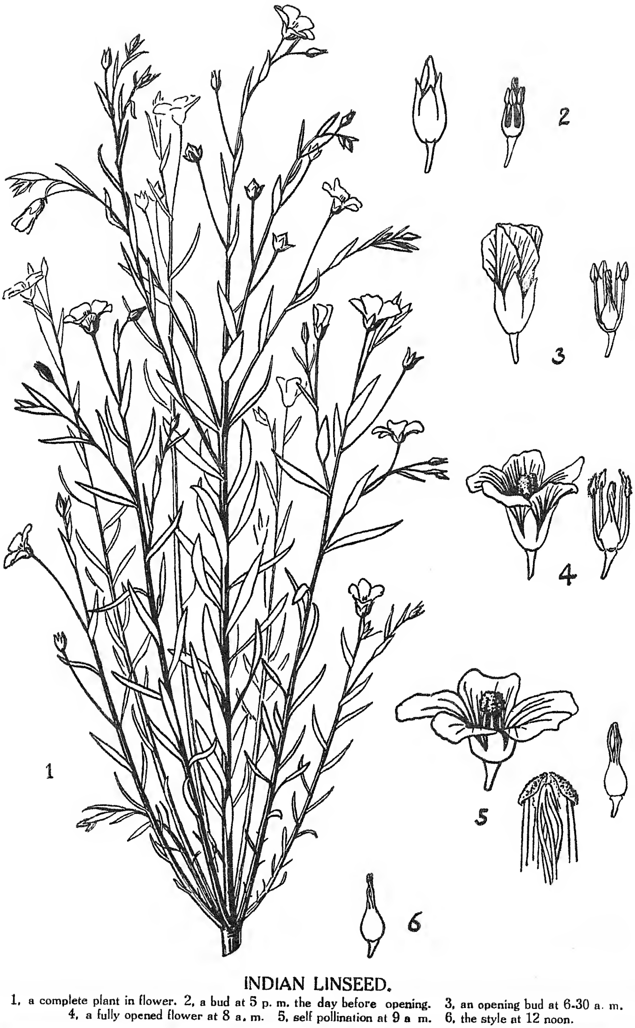
1. Linseed.

The mode of pollination of the European cultivated forms of linseed (*Linum usitatissimum* L.) grown for fibre purposes has been described in detail by Fruwirth[1] who found that self-pollination is the rule and that good setting is obtained under bag without loss of vigour.

For some years, a large collection of pure lines of Indian linseed, obtained from the black soil areas of Peninsular India and also from the plains, have been under investigation at Pusa and observations have been made on the flowers of this crop. Indian linseed is cultivated for the oil in the seeds and is a short, much branched plant with thick stems and numerous capsules very different from the types grown for fibre in Europe (Plate IV).

Flowering. The flowers open in the early morning and as a general rule in all such buds, the folded corolla is visible the evening before. In rare cases, however, a flower opens in which the corolla is not visible the previous evening. As soon as the corolla becomes visible, the filaments are still short and the unburst anthers stand well below the slightly twisted stigmas. The rapid growth of the filaments, however, soon brings the anthers to the same level as the stigmas and this is the position when opening begins. The time of opening of the flowers depends chiefly on the temperature and humidity and to a less extent on the particular type. On warm mornings and when there is little or no dew, opening begins very early, while on cold dewy mornings the process is distinctly delayed. In February 1916, the following observations were made on this point :—

[1] Fruwirth. *Die Züchtung der landw. Kulturpflanzen*, Bd. III, 1906, s. 45.



INDIAN LINSEED.

1, a complete plant in flower. 2, a bud at 5 p. m. the day before opening. 3, an opening bud at 6-30 a. m. 4, a fully opened flower at 8 a. m. 5, self pollination at 9 a m. 6, the style at 12 noon.

(1) February 9th. A cold day (max. temp. 70°F.; min. temp. 30°F.; temp. at 8 A.M. 47°F.).

No. of flower	Time of bursting of anthers	Time when opening of the flower was completed	Time of closing or falling of petals	Time of reopening of flower the following day
1	9–59	11–15	16–30	10–12
2	10–00	10–55	16–30	10–13
3	9–58	11–20	16–30	10–11
4	9–52	11–30	16–30	10–10
5	9–56	11–45	16–30	10–05
6	9–52	12–00	16–30	10–08
7	9–51	11–25	15–40	——
8	9–37	10–45	16–30	9–46
9	9–00	10–47	16–30	10–02
10	9–42	10–58	16–00	——
11	9–39	11–43	15–45	——
12	9–30	10–45	16–30	9–40

(2) February 6th. A warm day (max. temp. 86°F.; min. temp. 53°F.; temp. at 8 A.M. 61°F.).

No. of flower	Time of bursting of anthers	Time when opening of the flower was completed	Time of closing or falling of petals	Time of reopening of flower the following day
1	8–15	8–31	17–00	8–0
2	8–31	8–40	16–00	——
3	8–12	8–29	14–30	——
4	8–15	8–27	16–00	——
5	8–59	8–27	16–00	——
6	8–24	8–35	15–00	——
7	8–14	8–40	13–30	——
8	8–15	8–40	14–30	——
9	8–13	8–36	13–30	——
10	8–08	8–27	15–00	——
11	8–13	8–40	13–30	——
12	8–17	8–33	13–00	——

Thus the opening is not only delayed on cold days but flowers often reopen the following morning and the petals do not fall till the second day. On February 10th, 1916, a very warm day, some flowers began to show signs of opening as early as 3 A.M., while on February 9th, a cold day, opening did not begin till 7-30 A.M. As a rule on normal warm days, the flowers are fully open between 8-15 and 9 A.M. and from 10 A.M. to 12 noon on cold days. The petals begin to fall on the day of opening and this is generally completed by 5 P.M. A few, however, reopen the following morning and the number is considerably increased on cold and cloudy days.

Pollination. The anthers begin to burst longitudinally when the flower is half open and at this period they stand at a little distance from the crowded

stigmas and often at a slightly higher level. A few minutes later when the flower is fully open and the rupture of the anthers is complete, they close in on the stigmas and self-pollination takes place. Thus self-pollination takes place automatically by the help of the expansion of the corolla. At a little later stage, the burst anthers often fall together forming a cap over the stigmas—a movement which renders self-pollination a practical certainty. In many flowers it was observed that after the anthers begin to burst, twisting of the styles occurred which helped to move the burst anthers through 90° thus bringing their pollen-covered surfaces close to the stigmas. This twisting also brought the stigmas to a slightly lower level and so assisted the burst anthers to fall together and form a cap over the stigmas. In many cases the styles untwist after the anther cap is formed, a circumstance which still further favours self-pollination.

Cross-fertilization. Small bees visit the flowers for honey about 10 A.M. While collecting honey from the five nectaries, they occasionally come in contact with the burst anthers and with the stigmas so that cross-pollination is possible. That crossing may occasionally take place in India has been proved by a study of the cultures obtained from the seed of single plants. In 1916, the seed of 340 bagged plants was sown of which 334 bred true. Splitting took place in six cultures only—one gave rise to plants with different shades of blue flowers while five cultures produced plants differing in habit of growth. In 1917, the seed of 233 bagged plants was sown. All bred true except one which split as regards habit and flower colour. In 1918, the seed of 232 bagged plants was sown all of which bred true. All these observations indicate that in the field crossing is more frequent than would be suspected from a study of the flower. That this is so was confirmed by the results of sowing separately the unbagged seed of all the cultures raised in 1917. In these 233 cultures, stray plants were found in five cases as follows :—

No. 1 (white flowers). Two blue-flowered plants appeared which next year gave 84 blue and 32 white-flowered plants in one case and 129 blue and 34 white in the other, or a total of 213 blues to 66 whites.

No. 23 (white flowers). One blue-flowered plant occurred which gave next year 52 blue-flowered and 12 white-flowered plants.

No. 165 (white flowers). One blue-flowered plant was found which next year gave 84 blue-flowered to 19 white-flowered offspring.

No. 170 (pale blue flowers). One dark blue-flowered plant appeared which split as regards shape of petals, colour of pollen (white or yellow), and colour of petals—white and shades of blue from very pale to very dark blue. The ratio of total blues to whites was 264 : 7.

No. 217 (blue flowers). In this, three pale blues appeared which split next year into 8 blue and 342 pale blue, 4 blue and 133 pale blue and 4 blue and 278 pale blue.

A similar experience occurred in 1918. In 232 cultures from unbagged seed a total of 15 stray plants were found in nine of these cultures. In all probability many of these are natural crosses.

These examples are sufficient to show that natural crossing is more common in Indian linseed than would be supposed from a study of the flower. The cases are sufficiently numerous to make it clear that in exact work with this crop all seed must be raised under bag. This does not interfere with setting and as far as our observations go there is no falling off in vigour produced thereby.

2. Taramira or duan.

Taramira or *duan* (*Eruca sativa* Lam.) is a common cold weather oil seed crop in the drier areas of North-West India, where it is commonly grown mixed with gram or barley. The oil is used for lighting purposes and to a great extent as human food. The inflorescence is a corymbose raceme, the petals are greenish yellow with dark, often purple veins and the pods, which contain numerous light reddish brown seeds, are closely adpressed to the stem.

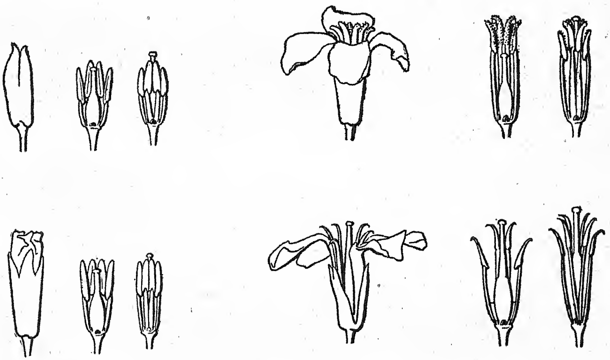


FIG. 2. Long and short styles in the flowers of *Eruca sativa*.

Pollination. The flowers open in the morning between 9 A.M. and 12 noon remaining open for about three days. Nectar begins to be secreted some time after opening takes place and is produced freely on the second and third days.

Generally two flowers on the same inflorescence open daily and as they last about three days it is usual to find six flowers open on the same branch. The anthers dehisce shortly after the flowers open and their pollen-covered surfaces are always turned towards the stigma. There are two types of flowers—long-styled and short-styled (Fig. 2). This difference in the length of the style can be distinguished in the bud stage and as the flower opens but it is most evident at the time the anthers burst. Afterwards it becomes lost as the flowers fade. Bees visit the flowers for honey up to the time the petals fall so that both self and cross-pollination are possible.

Fertilization. A considerable amount of work has been carried out on the fertilization of this plant. In 1909-10, fourteen samples of *taramira* from different parts of India where this crop is grown were sown at Pusa when it was observed that all the cultures were composed of a large number of very different types. Three hundred and thirty-four single plants were allowed to flower under bag but almost all failed to set seed—a very few seeds were found in only a few cases. A similar result was obtained the following year in the case of 402 plants. In 1911-12, a number of flowers were self-pollinated (either with pollen from flowers of the same inflorescence or from another inflorescence of the same plant) while others were cross-pollinated from different plants. In all cases the seed and pollen parents were bagged and every precaution was taken to avoid contamination with foreign pollen. The results are given in the following table :—

Flowers bagged and afterwards left untouched		Flowers selfed				Cross-pollinated from other plants	
		Pollinated from flowers of the same inflorescence		Pollinated from flowers of another inflorescence on the same plant			
Flowers treated	Pods formed	Flowers treated	Pods formed	Flowers treated	Pods formed	Flowers treated	Pods formed
79	0	18	1	42	6	24	24
		24	1	13	0	30	30
				20	0	13	13
				19	0	14	14
				16	0	18	17
				36	6	10	10
				22	4	10	10
				43	0	12	10
						34	34
79	0	42	2	211	16	165	162
		These 18 pods as a rule contained only one seed each.				Pods well filled with seed.	

The following year the selfed and crossed seeds in the above experiments were sown side by side. Only two of the selfed seeds germinated and the plants so produced were shorter and less vigorous than those raised from the crossed seeds. These results show that self-fertilization is exceedingly rare in this crop and that practically all setting is a result of cross-fertilization. The crop is, in consequence, a mass of freely crossing heterozygotes. It is possible that the self-sterility met with is a consequence of the existence of heterostyly. The self-sterility observed may turn out to be the consequence of illegitimate pollination. This was confirmed by the results of some preliminary experiments carried out at Quetta in 1919. When long and short styled plants were crossed, the flowers set seed freely.

3. Til.[1]

Til (*Sesamum indicum* L.) is the source of most of the sweet oil used in India where it is grown as a summer crop in the colder regions and as an autumn or winter crop in the warmer tracts. *Til* prefers a light soil and is usually grown as a mixed crop.

Flowering. As the various forms of cultivated *til* vary very greatly in habit, time of flowering and in growth period, it is only possible to give a general idea of the conditions under which flowering takes place. The flowers are borne in racemes, either singly or in twos and threes in the axils of the upper leaves and possess very short pedicels (Fig. 3.)

Both the main stem and the side branches, which in some types are very numerous, bear flowers in acropetal succession. In the case of some early types observed at Pusa in 1911, the seeds were sown on May 5th and the first flowers appeared on June 16th when the plants were eighteen inches high. By the time flowering was completed, the total height of the plants was 3½ feet. Usually two flowers are open at the same time on any one inflorescence and in much-branched plants more than 20 flowers may be open at the same time. The plants are harvested before they are ripe to prevent the loss of seed by the splitting of the capsules.

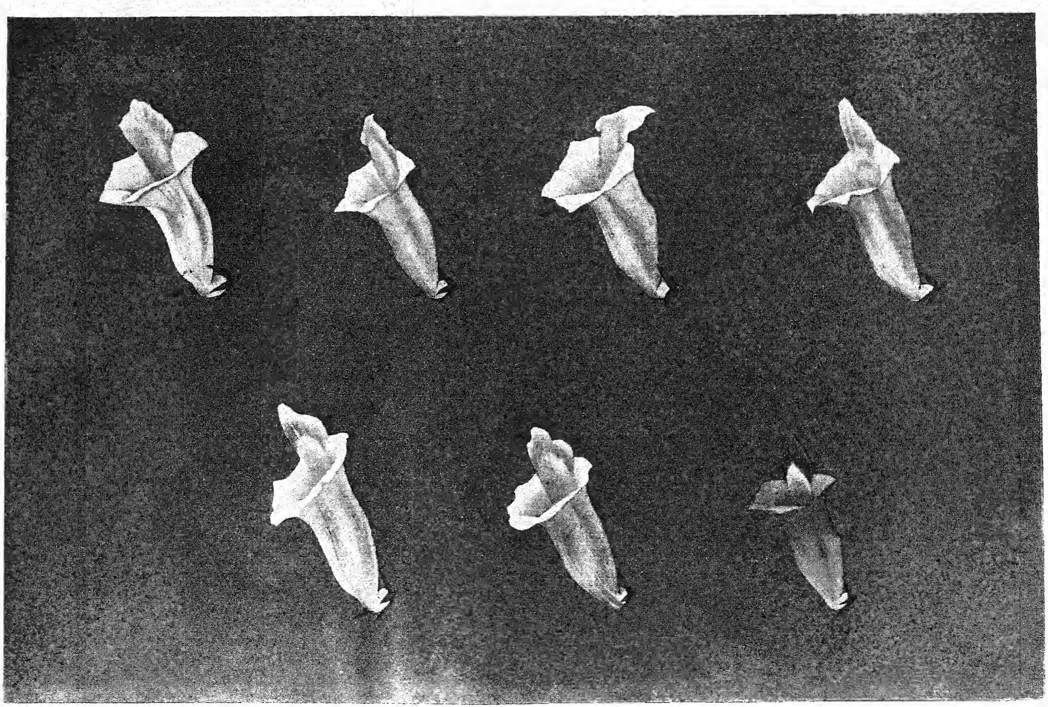
Pollination and fertilization. The flowers open between 3-15 and 4 A.M. and fade soon after midday, the corolla being shed without closing between 3 and 4 in the afternoon. They thus remain open not more than 12 hours. In the bud before the flower opens, the four unripe anthers are below the stigma

[1] *Die Züchtung der landw. Kulturpflanzen*, Bd. V, 1912, s. 182.

which at this period is not receptive. The anthers begin to burst longitudinally after 4 A.M. and commence to liberate their pollen. At this time the two hairy lobes of the bifid stigma often begin to separate and become receptive. The position of the anthers and stigma at this period is as follows. The fork of the bifid stigma and the centre of the anthers of the two long stamens are at the

FIG. 3. A flowering branch of *Sesamum indicum*.

same level while the anthers of the two short stamens are at a lower level. Like other members of the order to which *til* belongs, the stigmas are irritable and the two lobes separate when touched. This causes one of the lobes of the stigma to move down between the two burst anthers of the long stamens.



TYPES OF COROLLA IN SESAMUM INDICUM.

As all these organs are practically in contact, self-pollination is easy. By five in the morning, the stigma is generally covered with pollen and as insects are not observed till 6 A.M. a great deal of self-pollination is bound to take place. Very frequently, however, the anthers in some flowers do not develop but remain aborted and turn brown without shedding any pollen. In these cases the visits of bees easily bring about cross-pollination and it is probable that most of the cross-fertilization which takes place in this crop is due to this cause. Setting readily takes place under muslin and the seed so produced develops normally. In 1910, the seeds of a large number of single plants of *til* were sown separately at Pusa and the progeny examined. There was no doubt that many of these were heterozygotes and that natural crossing in this crop is considerable.

Varietal characters.

During the years 1909 and 1910, a good many sowings of *til* were made at Pusa, the seed in the first instance being that usually grown by the people in the various parts of India. From the 1909 crop, the seed of single plants, both free flowering and bagged, was saved in a large number of cases for sowing the next year. These cultures have enabled a preliminary study of this crop to be made. While many of the single plant cultures showed that they were raised from heterozygotes, nevertheless some bred true and from these it was observed that the Indian types of *til* differ in the following characters :—

1. *Colour of seeds.* The full development of the colour of the seed coat appears to be a question of development. White and brownish seeds are met with on the same plant while with black seeds, smoky and dark brown individuals occur. Further investigation of this matter is desirable.

2. *Rough and smooth seeds.* As a rule, the surface of the seeds is smooth. In the cultures raised from some heterozygotic smooth parents, however, some plants with rough seeds were produced. No homozygotes with rough seeds were isolated.

3. *Colour of corolla.* Several different colour types are met with from almost pure white to deep violet. (Plate V.)

4. *Hairiness and smoothness of corolla and capsule.* Forms with numerous hairs as well as less hairy types occur.

5. *Number of flowers in the leaf axils.* At first sight it would appear that in all the varieties of *til* three flowers in each leaf axil would be usual. As a rule, however, only one flower is produced, the other two bud-like bodies

developing into extra floral nectaries. Sometimes, instead of one flower and two nectaries, three flowers are developed and in these types there is little or no branching. This pair of characters however is not always differentiated as some plants bear two or three flowers in each leaf axil at the tips of the branches only while on the rest of the plant there is only one in each axil.

6. *Divided and entire leaves.* As a rule the leaves of this crop are entire except when the vegetative vigour is great as happened in 1909 at Pusa. Most of the plants had divided leaves and very few entire-leaved plants were seen. In the following year, when the plants were sown later and the vegetative vigour was less, entire leaves were common. It would appear likely therefore that the form of the leaf depends on the conditions of growth and in any case further study of this leaf character is required before it can be used for breeding purposes.

7. *Branched and unbranched habit.* Those types with one flower in the axil are generally much branched while those with three flowers have few or no branches.

8. *Earliness and lateness.* There is a great range as regards this character. Some of the Indian forms are so late that they can hardly be grown at Pusa.

4. Niger.

Guizotia abyssinica Cass. is an important oil seed crop in Central and Southern India where it prefers a light sandy soil.

Pollination and fertilization. Examination of the capitulum shows that this plant falls into the sunflower group of the *Compositæ* and that the details relating to pollination are no exception to the general rule in this group. There is a marginal ray of 7 to 12 ligulate florets (female) surrounding a disc of 40 to 60 tubular hermaphrodite flowers. The flowering period of each capitulum extends from 7 to 8 days. The tubular flowers open in the early morning and liberate their pollen in the tube at the time of opening. The style emerges covered with pollen about noon, the stigmas separating and curling back to the staminal tube the same evening. Rarely do the stigmas in bending back touch the pollen on their own style, a circumstance which perhaps explains the failure of this crop to set seed readily under muslin. The self-fertilized seed formed under bag however germinates and develops normally. From the character of the flowering, cross-fertilization is generally to be expected but some self-fertilization is also likely.

Cross-fertilization. That cross-fertilization is common in this crop was proved in 1911 at Pusa by the examination of 29 cultures raised from the seed of single plants. Of these, 23 contained heterozygotes while the remaining six appeared to be uniform. Splitting took place in the following characters—time of maturity, colour of the stem (green, red and intermediate tints), habit (branching or erect), size and margin of the leaves, colour of the seeds and height of the plants.

IV. Crops grown for fibre.

1. Round podded Jute.[1]

The cultivation of *Corchorus capsularis* L., the principal source of the jute of commerce, is chiefly confined to the Districts of Bengal, which comprise the deltas of the Ganges and Brahmaputra. This species is distinguished from *C. olitorius* L., by its rounded fruits in which the seeds are not separated by transverse dissepiments. In vegetative characters and in general appearance, however, the two species are very similar to one another.

Flowering. The flowers are small and inconspicuous and arise both on the main stem and on the side branches. They occur in cymes on the stem opposite a leaf where a short peduncle arises. This branches into from three to six short pedicels, each bearing a single flower, which, as would be expected, open at different times. The flowering period depends on the earliness of the type. In sowings made at Pusa on February 13th, 1911, the first flowers appeared at the beginning of June and by the middle of July most of the red sorts were in flower. The flowering period lasts about six weeks after which no growth in length takes place.

Pollination and fertilization. A few flowers open about 8 A.M. but the majority open later between the hours of 9 and 10 A.M. The corolla closes between two and four in the afternoon, the flowers remaining open, on the average, not more than five hours. Next morning, the withered calyx, corolla, stamens and style are shed and the small fruits begin to develop. In the bud, the numerous 2-celled anthers are above the divided stigma. Both anther cells split longitudinally and liberate their pollen in the bud about an hour and a half before the flower opens. In the open flower, the anthers are still around and above the stigma and therefore the chances of cross-pollination appear to be small. Bees visit the flowers but not in large numbers. Bearing in mind

[1] *Die Züchtung der landw. Kulturpflanzen*, Bd. V, 1912.

the floral arrangements and also the moist atmospheric conditions which obtain in the jute tracts during the flowering time, self-pollination as a general rule is to be expected. The flowers set seed freely under nets and the seeds so produced germinate and develop normally.

Cross-fertilization. As a check on these observations, the seed of 46 single plants of various types of jute were collected in the autumn of 1910 and were sown separately during 1911 at Pusa. Thirty-eight of these cultures were uniform in all respects while eight showed the presence of heterozygotes. In one culture of 64 individuals, eleven plants with green stems and 53 plants with reddish stems occurred. In another culture in which all the plants had red stems, both light reds and dark reds occurred. In six other cultures plants with red and others with green petioles occurred.

Improvement. The prevalence of self-pollination and the comparative ease with which heterozygotes can be detected and removed before flowering takes place, render improvement by form-separation an easy matter. The distribution of improved types of seed presents no difficulties provided the bulk of seed is large enough for the systematic replacement of the country crop.

2. Long podded Jute.[1]

The cultivation of *Corchorus olitorius* L. for fibre is restricted to one portion of Bengal and is of importance only on high lying sandy loams in the Districts of Faridpur, Nadia, Hugli and Pabna. It is inferior as a source of jute and is hardly ever grown under the inundation indispensable to *C. capsularis* L. This species is much more branched than the forms of round podded jute and its fruits are long beaked pods in which the seeds are separated by transverse dissepiments. In other respects it greatly resembles *C. capsularis.*

Flowering. The small inconspicuous flowers are borne as simple cymes both on the main stem and on the side branches and occur two or three together with very short pedicels on a common short peduncle which arises on the stem opposite a foliage leaf. The lowest flower buds open first and flowering proceeds as the stem elongates, there being not more than two or three flowers open on each branch at the same time. The earliest formed flowers rapidly produce pods so that a single plant of this species carries ripe fruits below, while the upper portion of the stem is still growing in length and producing

[1] *Die Züchtung der landw. Kulturpflanzen,* Bd. V, 1912, s. 150.

buds and flowers. The flowering period varies from about a month in the early kinds to six weeks in the late types.

Pollination and fertilization. Some flowers begin to open early in the morning about 6 A.M. but generally this process begins at 7-30 A.M. and is completed an hour later. The flowers remain open for a short time only—not more than three hours as a rule—and begin to close at 11 A.M., the process being complete about noon. On the following morning, the withered calyx, corolla, and stamens as well as the style are shed. In the young bud, the much divided stigma is always above the unripe anthers and these relative positions are maintained till just before the flowers open. At this point, the filaments elongate rapidly and carry the very numerous bilobed anthers above and around the stigma. In those buds which open early, the anthers burst when the flower is half open, the stigma is then closely surrounded by a dense forest of bursting anthers and self-pollination ensues. In the case of buds, which open late, the anthers begin to burst before the flower opens and sometimes pollination takes place in the closed bud. These arrangements greatly favour self-fertilization and natural crossing is rare. No cases have been detected in the Botanical Area at Pusa. The fact that the cultivators in the District of Hugli grow two late varieties of the crop—one red-stemmed and the other green-stemmed—side by side and go to some pains to keep them separate points to the absence of extensive cross-pollination. Bees visit the flower sparingly when fully open. Setting takes place readily under nets and the seed so produced germinates and develops normally.

Improvement. The rarity of natural crossing and the fact that each plant produces a large quantity of seed will render improvement by selection and subsequent seed distribution easy matters. In view, however, of the small importance of *C. olitorius* in India compared with *C. capsularis* it is not likely that a large amount of work will be done on this crop in the near future.

3. Roselle.

The details relating to the pollination of *Hibiscus Sabdariffa* L. have already been described and figured in detail.[1] Self-pollination is the rule and setting takes place normally under nets without any loss of vigour. Up to 1911, no cases of natural crossing were detected at Pusa. Since that time, a considerable amount of work has been done on the inheritance of characters

[1] *Mem. of the Dept. of Agr. in India (Botanical Series)*, vol. III, 1910, p. 314, and vol. IV, 1911, p. 31.

in this crop and numerous cultures have been raised. A few cases of natural crossing have been observed due to the visits of humming birds. Although these cases are rare, it is desirable in exact work on this crop to raise all the seed for sowing under net.

QUETTA:
June 4th, 1919.

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LIST OF TEXT-ILLUSTRATIONS

KUMPTA COTTON AND ITS IMPROVEMENT.

BY

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I. Introduction.

One of the types of cotton most extensively cultivated in India is that strain or series of strains of *Gossypium herbaceum* which goes in the trade by the name of *kumpta*, or which, though called otherwise, is grown in adjoining tracts and is botanically and agriculturally indistinguishable from it. This cotton, which is variously known on the Bombay market as *kumpta*, *westerns*, *bagalkot*, *miraj*, or by many other names, belongs to one recognized botanical species, though the market value of the lint from various strains or mixtures of strains differs considerably, and though the agricultural value of these strains to the cultivators of the cotton is again by no means equal. It is the object of this memoir to give an account of the work done in the last few years in investigating the characters of the various strains of this cotton, as they occur in the cotton grown near Dharwar, and in isolating and developing types which have promise both from the point of view of the cultivators and of the trade. As the growing of types of *Gossypium herbaceum* as a commercial cotton is peculiar to southern and western Asia, and to the Mediterranean region, a short account of the characteristics of this species of cotton is prefixed before dealing with the special characters of the strains of *kumpta* cotton properly so called.

II. Gossypium herbaceum[1], Linn.

This species of the cotton plant, recognized from the earliest days of the classification of various cottons, seems to be almost entirely grown in southern

[1] In this discussion I am following Gammie's description of this species. Watt has named Gammie's *Gossypium herbaceum* as *Gossypium obtusifolium* var. *Wightianum* and considers that the true *Gossypium herbaceum* is a different species, identified with the so-called Levant cotton.

and western Asia.[1] It forms one of the chief cultivated cottons of India, and it is grown in China, and also in Persia. Beyond this, there is little or no clear or definite information. Gammie states that samples from Turkey, Greece, Armenia, Persia, Cephalonia, Crete, Khorasan, Afghanistan and Gilgit appear to belong to this species but then adds, "they may just as well be considered forms of *Gossypium obtusifolium*, Roxb."[2] In India, however, its cultivation is very widespread. Typical *Gossypium herbaceum* is grown as *lalio* in Kathiawar and Northern Gujarat, as *broach*, *surat*, *kahanmi*, *ghogari* in Gujarat, and as *kumpta* and the other commercial types mentioned above (*see* page 221) in the centre of Peninsular India. Types of the cotton plant distinguished by Gammie as separate varieties occur in the *mungari* or *bellai*, *uppam*, *northerns* of Cuddapa, as a mixture in *karunganni*, and one or two other kinds in Madras, and in the *wagad* or *sakalio* of Gujarat.

Gossypium herbaceum has been supposed by some to be a cultivated form of *Gossypium obtusifolium*[3] which is found wild in many places in the Southern Maratha Country (Badami, Gokak, etc.), and also in Sind. This wild plant is declared by Cooke to be a wild condition of *Gossypium herbaceum* var. *Wightianum*, or a hybridized form with perhaps *Gossypium neglectum*.[4] It is undoubtedly, however, *Gossypium obtusifolium* simply.

The botanical characters of the typical *Gossypium herbaceum* have been defined in detail by Gammie (*l.c.*). The most characteristic features from this point of view are the fact that the basal branches are long and spreading, which causes Leake[5] to class this species among the monopodial types of cotton. The corolla is yellow, with a black eye, fading to yellow suffused with red, somewhat larger than the bracteoles. The type is, in fact, well known, though systematic authorities are by no means yet in agreement as to the name which properly belongs to this species. Watt classes most of the *herbaceum* cottons under discussion as *Gossypium obtusifolium* var. *Wightianum*. The exact name given to the group of cottons, as defined by Gammie and others, is not perhaps an important matter.

There are, however, several characteristics of the various types known together as *Gossypium herbaceum* in cultivation, which are important in considering this type as an agricultural plant. They are as follows :—

[1] De Candolle considers that probably it was originally limited to the south and east of India.

[2] The distribution is well described in Watt's "Wild and Cultivated Cotton Plants of the World," pp. 143–153 (1907). *See* also Cooke. *U. S. A. Dept. Agric. Bur. Plant Ind. Bull. No. 88.*

[3] Dalzell and Gibson. "Bombay Flora," p. 8 (Supplement), 1861.

[4] Cooke. "Flora of the Presidency of Bombay," London, 1903, p. 117.

[5] Leake. *Journal of Genetics*, 1911, Vol. I, p. 209.

(*a*) The *herbaceum* cottons all have a somewhat long-growing period as compared with most of the other cultivated Indian types. When it grows normally, *broach* cotton is planted in June, and the picking is not complete till the following March. *Kumpta* cotton, planted usually in Dharwar in August or September, often is still ripening cotton bolls in the following May. The reason for this very long period of growth (or rather of boll production) will appear later, as a result of the occurrence of several different kinds of bolls on the plants.

(*b*) The seeds are always covered with fuzz,[1] the fuzz being white in this case, and the seeds are relatively large. The result of this latter point is that, compared with other cottons, the percentage of lint to the weight of the seed cotton (ginning percentage) is usually not very large. Taking a large number of samples examined by Gammie,[2] and not distinguishing varieties, the average ginning percentage works out with three fairly largely grown species as follows :—

	1902–03 Per cent.	1904–05 Per cent.
Gossypium herbaceum	29·1	29·4
Gossypium indicum	31·0	33·1
Gossypium neglectum	31·6	33·5

Of course, in each of these species the variation is large, and in each case there are strains with much higher ginning percentage than others. Thus among the *herbaceum* cottons the *ghogari* of Gujarat has a high ginning percentage, and the *kumpta* has a low one, and similar differences occur among the others. But, as a general rule, the *herbaceum* cottons have larger seeds and a smaller percentage than most other types of Indian cottons.

(*c*) The *herbaceum* cottons, as a rule, are far more bushy in habit than most other species of cotton. This is the result of their bearing a number of the so-called monopodial branches. The bushiness even among the *herbaceum* cottons varies very much indeed, and the differences among the strains are characteristic, as we shall see, of the varieties grown in different regions. But though these differences occur, yet even the less bushy strains of *herbaceum* cotton usually appear far more bushy than other species. Other cottons, in fact, bear their cotton almost entirely on sympodial branches; the *herbaceum* cottons bear their bolls also in large measure on the monopodia or on the axillary branches. One of the results of the fact that bolls are produced

[1] Except in one form of *herbaceum* cottons from Madras (*see* Gammie, *l.c.*).

[2] "Indian Cottons," 1905, pp. 21–28. Gammie now thinks (private communication to the author) that these figures should be revised and that *Gossypium indicum* has probably on the whole a lower ginning percentage than *Gossypium herbaceum.*

largely on three types of branches—monopodia, sympodia, and axillaries—which are developed at different stages of the plant's growth, is that the *herbaceum* cottons bear during a very long period, or, in other words, tend to ripen bolls over a good many months.

(*d*) The *herbaceum* cottons can, as a rule, be distinguished among other varieties by the light, rather yellowish, green colour of the leaves and stems. Other cotton plants are nearly all very much darker green in colour. So much so that a field of a *herbaceum* cotton looks almost unhealthy to anyone who has been accustomed to deal with other species of cotton.

(*e*) The bolls of the *herbaceum* cottons are much rounder in shape than those of almost any other variety. This character will be seen in Plate I, where a number of types of bolls found in *kumpta* cotton are illustrated. But whether we have to deal with the small-bolled *kumpta*, or the much larger-bolled *herbaceum* cottons of Gujarat, the roundness of the boll is a feature of *Gossypium herbaceum*. This roundness varies a good deal, and there is a general belief among the growers that more elongated bolls tend to give a longer staple cotton than round bolls, but the correlation between these characters has never hitherto been investigated.

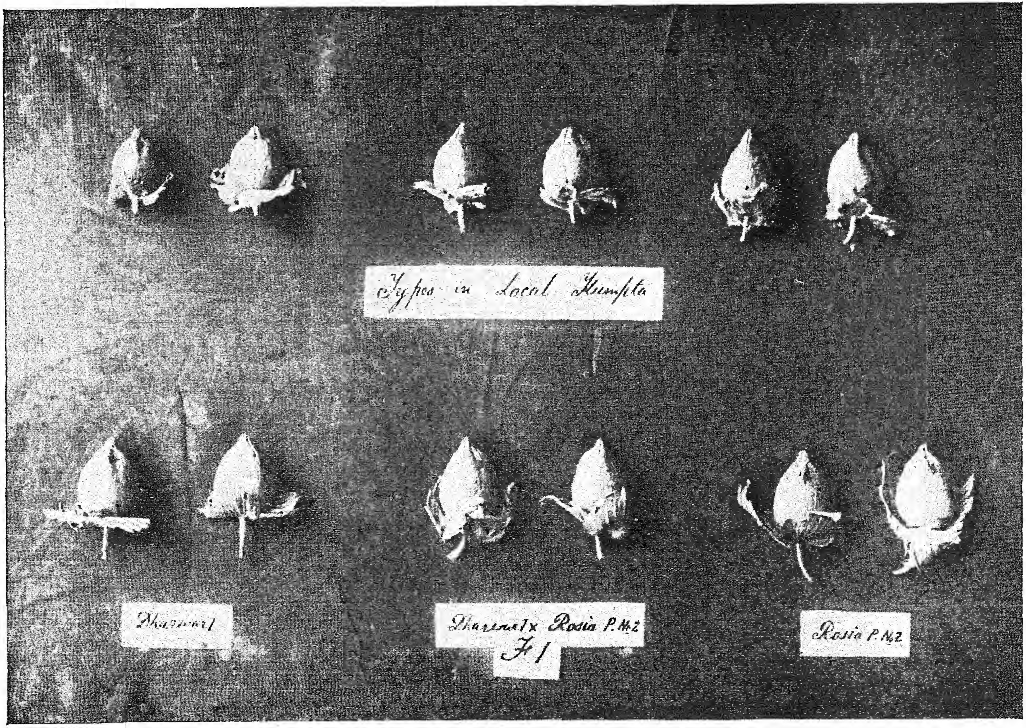
These various characters of the *herbaceum* cottons when grown as agricultural plants mark them off from their congeners, tend to give a large crop of low-ginning cotton, and lead to the limitation of their distribution to places where a long-growing period is possible either on account of a well-distributed rainfall or irrigation, or on account of the absence of the likelihood of frost. Where the growing period can only be short, for whatever reason, other types of cotton tend to prevail which may not yield so well, but which ripen quicker, and which often, though not always, in India, give a cotton of inferior staple.

III. "Kumpta" cottons.

One of the most important types of *Gossypium herbaceum* cultivated in India is that known commercially under the name *kumpta*, a name probably derived, as Mollison[1] notes, from the fact that much of the cotton produced in the *kumpta* tracts reached Bombay, in the pre-railway days, *viâ* the port of Kumpta in North Kanara. The name is more restricted than the type of cotton, and this latter spreads continuously over a very large area in the Southern Maratha Country of the Bombay Presidency, as well as into Mysore and the Nizam's Dominions. The attached map (Plate II) shows for the Bombay-British districts the intensity with which it is cultivated. It, however,

[1] "Textbook of Agriculture" (1902), Vol. III, pp. 200–201.

PLATE I.



Types of boll in *Kumpta* cotton, and in a cross with *Gossypium neglectum*.

reaches Bombay under various names among which *miraj*, *bail-hongal*, *bagalkot*, *westerns*, and many others are recognized. Except for a relatively small area in the eastern part of the Dharwar District and adjoining tracts where a form of *Gossypium hirsutum* is grown, known as Dharwar-American, it is the dominant cotton in almost all the area where it is grown, gradually disappearing, however, in favour of types of *Gossypium neglectum* in the north of the Bijapur District and portions of the Nizam's Dominions, and in favour of types of *Gossypium indicum* in other districts of the Nizam's Dominions.

The present paper is, however, almost wholly concerned with *kumpta* cotton as it occurs in the Dharwar District which, with the southern part of the Bijapur and Belgaum Districts, remains the head centre of its cultivation. This cultivation is probably of very old standing, though the descriptions of the local cottons grown seem to have interested few of the cotton workers of the last century. The reports of the older work on cotton in the Southern Maratha Country in the years between 1830 and 1870 are full of accounts of American cotton and the vicissitudes which attended all efforts to introduce it. They rarely, however, refer to the cotton already grown. It was apparently beneath notice, though it is, as a matter of fact, almost as valuable as that American for whose introduction so many pains were spent.

Since 1870, however, a few interesting notices of this cotton as cultivated in its own districts have been presented. Drury[1] in 1873 mentions that the yield may go up to 500 pounds per acre, presumably of seed cotton. The most interesting account of the cultivation of *kumpta* cotton, however, is that given by Walton[2] in 1880. He noted particularly that it is sown in August, and that earlier sowing has not been a success. He mentions that Dharwar-American cotton (which he calls *G. barbadense*) has replaced *kumpta* over parts of Belgaum and Bijapur. But the most interesting point he makes is that the cultivators object to manuring directly for *kumpta* cotton, an objection still maintained by the people. Watt[3] adds very few facts but notes that the area of *kumpta* cotton in the three districts of Dharwar, Belgaum and Bijapur was 1,118,250 acres in 1883, but had dropped to 968,300 in the years before 1890.

I may quote two or three other authorities who note various points about *kumpta* cotton, before going on to place my own observations on record. The

[1] "Useful Plants of India," 1873, p. 233.

[2] Walton, W. "Cotton in Belgaum and Kaladgi Districts," 1880.

[3] Watt. "Dictionary of Economic Products," Vol. IV, p. 59 (1893), and also "Wild and Cultivated Cotton Plants of the World," p. 150 (1908).

first of these is Middleton[1] who grew the *kumpta* cotton in Gujarat, and mentioned that, though grown side by side with Dharwar-American cotton for many years, it shows no trace of hybridization with it. Gammie[2] in 1905 gives a few further details with regard to distribution and specially remarks on the now well-recognized fact that the stiffer soils in the Bombay Karnatak are considered most suitable for *kumpta* cotton, while Dharwar-American cotton occupies the lighter lands.

Since the above, the remarks on *kumpta* cottons grown in the Bombay Karnatak are few and far between. The recent report[3] of the Indian Cotton Committee notes, however, as follows :—

"It may be mentioned that *kumpta* as is the case with other varieties of *herbaceum* is possessed of very stable characteristics and that it is therefore difficult to produce anything in the nature of a recognizable improvement in it. Recent researches have, however, shown that the quantity of the crop can be sensibly increased by a change in the mode of growth. Such a change can be brought about by a selection of an early maturing type, the characteristics of which are an upright habit of growth with many fruiting branches and few vegetative branches. This character is freely inherited, although it is sometimes masked by the check caused in the leading shoot by the borer which attacks its pith. The selections which are being made all conform to this type which furnishes a distinguishing mark capable of easy detection on the field, where plants of the bushy type are most prevalent. The more compact habit permits of closer planting and therefore results in a heavier crop."[4] "It is at its best in Belgaum but is almost equally good in Dharwar, falling off in quantity further eastward. It differs from the variety of *Gossypium herbaceum* grown in Gujarat in its shorter period of growth, smaller bolls, and lower ginning percentage, the latter being 26. The staple of the *kumpta* variety is $\frac{7}{8}$ inch in length."[5]

Present distribution of "kumpta" cottons in the Bombay Presidency.

The present distribution of *kumpta* cotton growing in British section of the Bombay Presidency is almost limited to three districts, Dharwar, Bijapur and Belgaum, though there is a little in Satara. In the first of these it shares the cotton area with the so-called Dharwar-American type, and to a less extent

[1] Middleton. *Agricultural Ledger No.* 8 (1895).
[2] Gammie. "Indian Cottons," Calcutta, 1905.
[3] "Indian Cotton Committee Report," 1919 (Calcutta).
[4] *Ibid*, paragraph 123.
[5] *Ibid*, paragraph 117.

in recent years with Cambodia, and with *broach* cotton. So far as the area under these last two cottons is concerned, there are no statistics available, but the area under *kumpta* and Dharwar-American cotton is separately recorded and is indicated below for the two types of cotton—

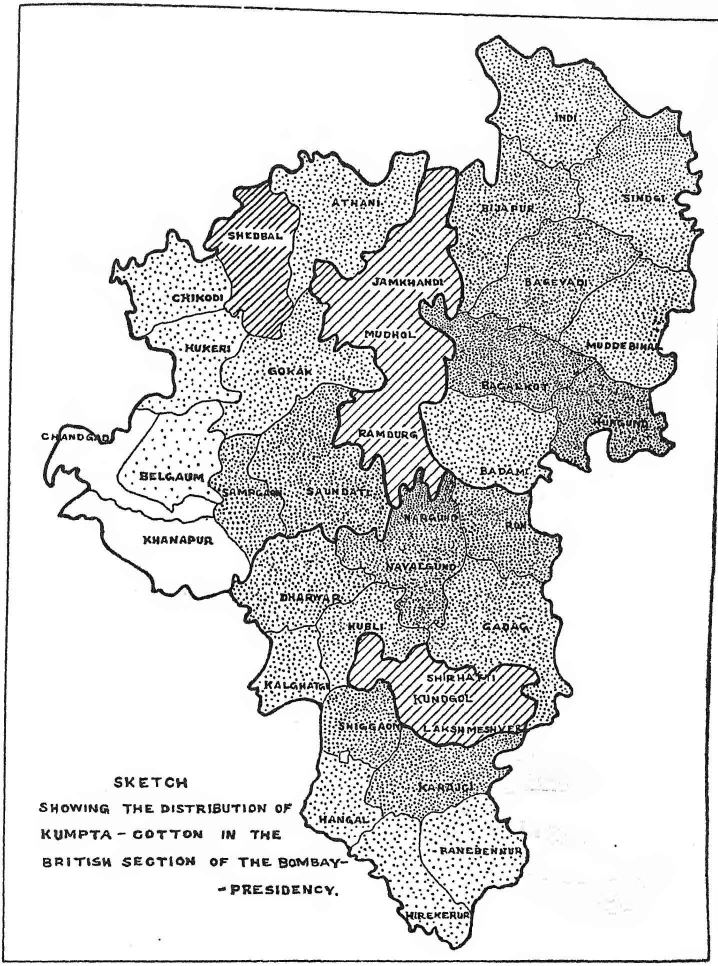
	"Kumpta" cotton		Dharwar-American cotton	
	Average area, 1908–12	Area, 1918–19	Average area, 1908–12	Area, 1918–19
	Acres	Acres	Acres	Acres
I. Dharwar District ..	388,000	403,343	229,769	261,118
Talukas.—				
Dharwar ..	26,462	36,543	658	..
Hubli.. ..	39,650	24,725	19,298	32,826
Gadag ..	55,981	60,234	81,682	73,889
Ron.	23,869	49,125	74,346	43,502
Navalgund ..	65,159	99,063	16,842	22,215
Haveri ..	34,308	55,120	7,272	20,926
Ranebennur ..	20,769	14,856	29,862	40,937
Bankapur ..	41,287	30,218	..	16,706
Kalaghatgi ..	2,791	11,006	..	..
Hangal ..	8,367	10,250	..	1,837
Kod.	7,384	12,203	..	8,280
Mundargi ..	..	..	..	..
Nargund ..	33,433	..	..	..
II. Bijapur District ..	584,168	526,299	99,408	122,037
Talukas.—				
Badami ..	40,111	38,165	..	..
Bagalkot ..	78,815	95,825	315	..
Bagewadi ..	90,494	75,393	..	35,000
Bijapur ..	62,468	64,255	..	..
Hungund ..	81,919	77,129	9,465	32,809
Indi.	23,577	56,186	5,048	120
Muddebihal ..	1,38,788	49,346	21,411	48,897
Sindgi ..	62,422	70,000	564	5,211
III. Belgaum District ..	235,489	208,787	..	..
Talukas.—				
Belgaum ..	3,450	4,727	..	..
Khanapur ..	92	86	..	..
Chandgad ..	..	..	..	..
Sampgaon ..	27,097	28,087	..	..
Parasgad ..	73,162	75,826	..	..
Gokak ..	40,232	37,879	..	..
Chikodi ..	13,044	11,843	..	..
Hukeri ..	6,359	9,046	..	..
Athani ..	71,898	41,293	..	..

The distribution of these two cottons is shown in the accompanying sketch maps (Plates II and III). The *kumpta* cotton is obviously the dominant cotton in these three districts. It is exclusively grown in Belgaum. In Dharwar, where the American introductions of the last century have taken deepest root, these latter vary between 34 and 39 per cent. of the cotton area. In Bijapur Dharwar-American cotton only occupies from 13 to 15 per cent. of the cotton area, and a small but indefinite amount of *Gossypium neglectum* and *Gossypium indicum* cottons are also grown in the north and east of the district. It will be seen that in the British districts of the Bombay Presidency only, there are over 1,200,000 acres under this cotton on the average.

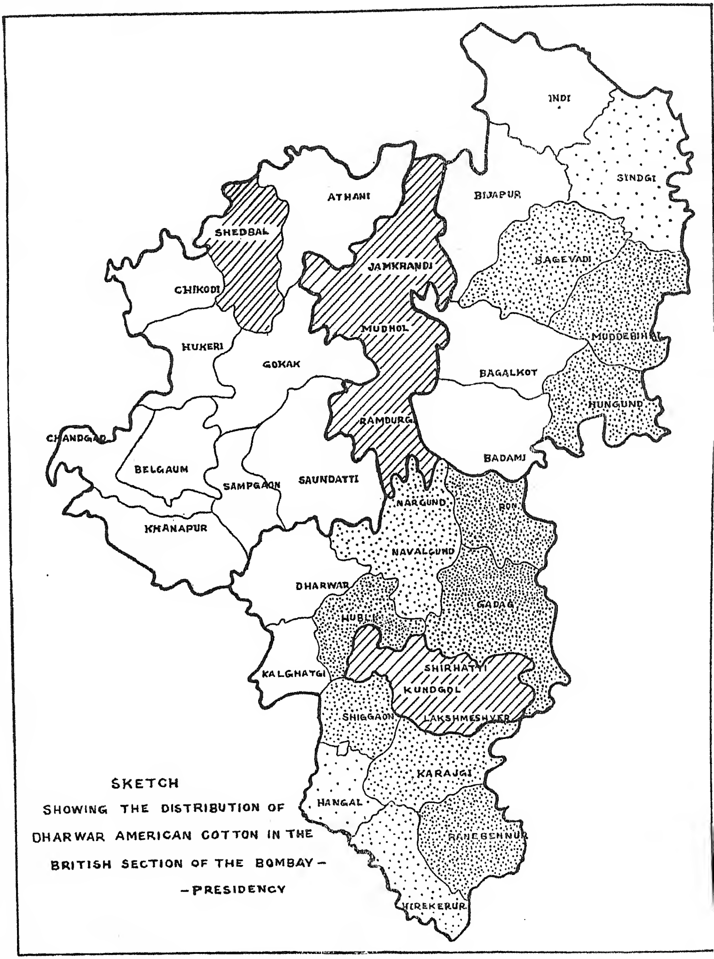
The tract in which it will be seen from these figures that *kumpta* cotton is cultivated, possesses features of climate and soil which distinctly mark it off from most other Indian cotton areas, and which seem to be peculiarly favourable to the types of *Gossypium herbaceum* which go by this name.

Soils of the kumpta tract. First with regard to soil. We are here at the southern extremity of the great area of black cotton soil derived from the Deccan trap. In fact it is in this region that the Deccan trap disappears, and the soils derived from it are replaced partially or wholly by those resulting from old sandstones and quartzites in the Belgaum and Bijapur Districts and from shales and schists in the Dharwar area proper. The soils are, therefore, very variable. Where the soil is chiefly a highly decomposed trap soil, it is usually very stiff and clayey; where it is entirely derived from the other rocks mentioned, it is usually light in character; while where there are mixtures of the two it has an intermediate character. The *kumpta* cotton is almost entirely restricted to the deep black almost pure trap soils, and to the medium black soils which consist of a mixture of trap soil with that derived from the other rocks. In other words, it is restricted most largely to the stiffer kinds of land. This is also largely true, though not to the same extent, of Dharwar-American cotton, for this latter is also grown and yields well on some of the red soils of southern part of the Dharwar District. So far as the *kumpta* cotton is concerned it seems universally found that under the climatic conditions found in the area under discussion, a shallow or light soil means a poor outturn and a low ginning percentage. In other words, the yield and ginning percentage both fall off as the soil becomes less retentive of moisture.

Rainfall of the "kumpta" tract. The districts in which *kumpta* cotton is grown can be divided, so far as rainfall is concerned, into three areas. To the



(Each dot represents 100 acres of Cotton. Cross-hatched areas are Native States)



(Each dot represents 100 acres of Cotton. Cross-hatched areas are Native States.)

west, there is the so-called *malnad* tract, with heavy rainfall, light soil, and practically no cotton. East of this lies the typical *kumpta* area, where in the east of the Belgaum District and the centre of the Dharwar District lies the transition tract, where rainfall, as typified by Dharwar itself, amounts on the average to 30 to 35 inches per annum. The actual average at Dharwar for a period of forty-three years is 32·7 inches. To the east of this section lies a drier tract where *kumpta* cotton is still grown, embracing the greater part of the Bijapur District and the east of the Dharwar District. Here the average rainfall is usually below 25 inches per annum. At Gadag, a typical centre, the annual average rainfall for forty-three years has been 24·9 inches.

The striking feature of the rainfall in the *kumpta* tract is not, however, the total amount, but rather its distribution. This distribution extends over a much larger period of the year than is the case in most Indian cotton districts with the exception of those of the south of the peninsula. The most frequent amount of rain received in each month (the 'mode'), at the two typical centres above named (Dharwar and Gadag), is as follows, taken from the records of forty-three years :—

	Dharwar (Transition tract)	Gadag (Dry tract)
	Inches	Inches
January	..	..
February	..	..
March	0·5	..
April	1·5	1·0
May	2·5	2·0
June	5·0	2·5
July	5·0	2·5
August	4·5	1·0
September	1·5	5·0
October	3·5	3·0
November	0·5	0·5
December	..	..

This distribution of rainfall is shown in Text-figure 1. In Dharwar there is substantial rain from May to October, and often some in April also, the

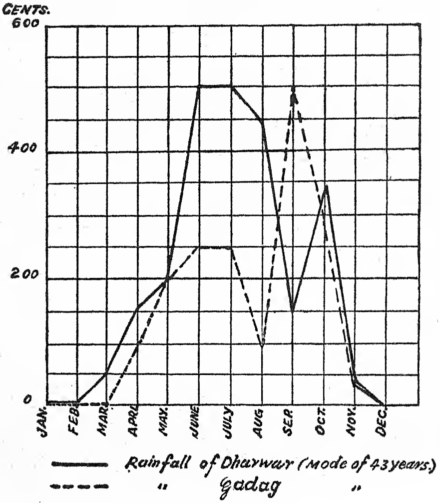
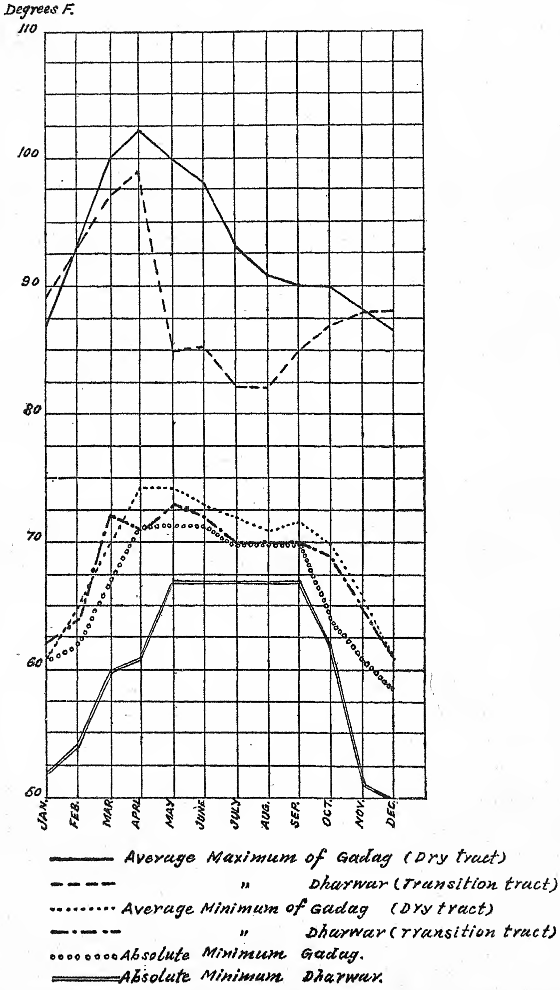


Fig. 1.

heaviest rain coming before sowing, and giving a thoroughly saturated seed bed for sowing the cotton in August. In Gadag the heaviest rain comes later—in September—but the rainfall is, nevertheless, fairly well distributed during the months from May to October.

Temperatures in the "kumpta" tract. The portion of the district I have named the transition tract above is temperate; the drier area to the east is very hot during March, April and May. The variations in the maximum and minimum temperatures from month to month are well shown in Text-figure 2. The generally higher temperature of the eastern drier tract is very obvious, and this is most marked in the months from May to August. From a cotton growing point of view, however, the most striking feature is that the average minimum temperature for the whole year in both cases is above 60°F. This enables cotton to be growing through the cold weather, and, in fact, over the whole of this tract the *kumpta* cotton grows throughout the coldest part of the year. The absolute minimum temperature during 20 years was 50°F.


Degrees F.
110
100
90
80
70
60
50
JAN.
FEB.
MAR.
APRL.
MAY
JUNE
JULY
AUG.
SEP.
OCT.
NOV.
DEC.
Average Maximum of Gadag (Dry tract)
" Dharwar (Transition tract)
Average Minimum of Gadag (Dry tract)
" Dharwar (Transition tract)
Absolute Minimum Gadag.
Absolute Minimum Dharwar.

F.G. 2

Methods of growing "kumpta" cotton. Although there are few peculiarities in the cultivation of *kumpta* cotton, a few words may be said with regard to it. The land is prepared for cotton by ploughing with the wooden plough, which generally goes three to four inches deep or a little more. The first ploughing is done after the fall of one or more good ante-monsoon showers in April or May. During the early part of the rains, the land is simply harrowed once or twice and any stubbles of the previous *jowar* (*Sorghum vulgare*) thus removed. The seed is sown at the rate of seven pounds per acre in August or September. The second half of August is the most common time. The usual method of sowing is to drop it in the furrows of the drill, through bamboo tubes attached to the tines. The method is rather more expensive and less effective than drilling, even using the ordinary country drill of Gujarat. The distance between the rows varies from eighteen to twenty-one inches, except in some parts of Bijapur where it is twelve inches. The distance between the plants is very irregular, as no thinning is done to regulate it.

The rotation used is a two-course of *jowar* and cotton, or a three-course of *jowar*, cotton and wheat. Whichever is adopted the *jowar* alone is manured,* generally with five to six cartloads (about 2 tons) of cattle manure per acre.

The cotton is ready, usually, for the first picking in February, and three four, or five pickings at intervals of ten to fifteen days are needed to harvest the *kapas* (seed cotton). Belated bolls continue to be produced until the end of April or the beginning of May. The average yield of *kapas* in the *kumpta* districts is about 350 pounds of *kapas,* equal to ninety pounds of clean cotton lint, but there are many farms where 600 pounds of *kapas* is normally obtained.

IV. Variations in "kumpta" cotton.

Kumpta cotton differs from other types of cultivated *Gossypium herbaceum,* and notably from those grown in Gujarat in several particulars. In most of these, however, it is much more closely allied with the *herbaceum* cottons of Madras than with those of the north of the Bombay Presidency. The main points of difference with these last are as follows :—

(1) *Habit of growth.* The Gujarat *herbaceum* cottons (*broach, lalio, ghogari*) are bushy, that is to say, the normal type produces a number of vigorous monopodia. These are much less abundant in *kumpta* cotton, and hence by the side of the others, it appears to be erect and to possess much less of the bushy character. As we shall see, this quality varies very much in the various strains of *kumpta,* but the difference between the predominant type in the two cases cannot be mistaken.

* It is usually considered very bad practice to manure the cotton crop itself.

(2) *Length of growing period.* All *herbaceum* cottons, as I have noted before, have a long growing period, but there is a great difference in the actual average length in the cotton grown in different regions. The *herbaceum* cottons of Gujarat have a growing period longer by two months than *kumpta.* The former are usually planted in June : the *kumpta* is sown in August-September as above noted. But the crop is obtained at about the same time, that is to say, in February and March.

(3) *Leaf fall.* Another marked point of difference is the way in which the *kumpta* cotton plants lose the greater part of their leaves at the beginning of the cold seaosn. This does not occur with the *herbaceum* cottons of Gujarat. It is not a matter of climate, for the Gujarat cottons do not drop their leaves when grown in the *kumpta* region.

(4) *Size of boll.* The Gujarat *herbaceum* cottons have a large round boll quite distinct from the much smaller, slightly tapering boll of the *kumpta* cotton. Various types of this latter are shown in Plates I and VII.

(5) *Colour of cotton.* Another very marked feature is the different colour of the cotton lint. The *kumpta* cotton has always a dull colour with a tinge of red in it. The Gujarat *herbaceum* cotton, on the other hand, is very white and much brighter in colour.

(6) *Ginning percentage.* The usual ginning percentage of *kumpta* cotton is very low. In this feature, *herbaceum* cottons differ very much indeed, and the various types vary from 40 per cent. or more in the *ghogari* of Gujarat to 32 or 33 per cent. in *broach* cotton, and to 25 or 26 per cent. in *kumpta* cotton. Of all the cultivated types of *Gossypium herbaceum, kumpta* cotton has the lowest ginning percentage.

(7) *Seed characters.* The *herbaceum* cottons of Gujarat have as a rule large and very fuzzy seeds. The seeds of *kumpta* cotton, on the other hand, are smaller and much less covered with fuzz. The difference is again very characteristic, and enables the seeds of the two types to be at once distinguished.

While these features enable *kumpta* cotton to be easily differentiated from the *herbaceum* cottons of the more northern parts of the Bombay Presidency, it is not suggested that either one or the other, or in fact any variety as usually cultivated, is a single definite type. It has often been said that *kumpta* cotton is possessed of very stable characteristics. This has, in fact, been repeated (*vide supra*) in the recently issued report of the Indian Cotton Committee. But I have found it extremely variable and to consist of a large number of distinct strains with different cultural, botanical and commercial characters. True, the differences found are perhaps not so great as those

among the cultivated types of *Gossypium neglectum*, but the differences are, nevertheless, very great, and not only does the cotton grown in different places vary very much, but the plants in any field have markedly distinct characters.

Some plants, for example, grow tall, bearing hardly any monopodia, and almost exclusively sympodial branches; others bear a large number of monopodia. These two types are in marked contrast to the eye, the former giving an open plant and the latter one which appears crowded with leaves. Following the difference in form is a difference in ripening. The plant predominantly sympodial usually ripens early and uniformly; the plant with a large number of monopodia is late and irregular in ripening. The bolls in different plants vary much in size, a difference which is of considerable commercial importance, as large bolls mean more *kapas* from each boll. The shape of the bolls also differs much (Plates I and VII), though the differences are difficult to describe in words. Even illustrations do not fully show the variations in roundness and flatness which are easily recognized in the field.

The range of variations in an ordinary field of pure *kumpta* cotton hence became a matter of very considerable interest, and the following are the results of a study of this point conducted on cotton grown on the Government farm at Dharwar. The usual plan adopted was to take a large number of plants at random, and measure each character whose variation it was desired to test. The plants used for this purpose were never less than one hundred, and often numbered a thousand. These measurements were then plotted on a frequency curve in the usual manner. In this manner I have studied the variation in (1) the branching character of the plant, (2) the shape of the lobes of the leaf, (3) the shape of the bracteole, (4) the length of the flower petals and the length of the style, (5) the number of cells in the bolls, (6) the number of ovules in the cells, (7) the ginning percentage, (8) the weight of the seed, and (9) the average staple of the cotton on the seed. The results of these studies may now be given.

(1) *Branching of the cotton plant.* As has already been stated, cotton plants can be described as erect or bushy, when their difference in branching is considered. The bushy cottons bear a number of long vegetative branches or monopodia near the base of the plant, which spread out and cause the plant to cover a considerable area like a bush. In the erect cottons these monopodia are either entirely absent or their number is reduced. In this case most of the branches present are the so-called sympodia or fruiting branches. The bushiness of the plants is, therefore, measured by the number of monopodia on the plant.

A record of this number for 979 plants is as follows. The plants were taken at random, except that plants whose main stem was injured by insects were avoided :—

Number of monopodia		Number of times occurring ("Frequency")
1	..	0
2	..	82
3	..	268
4	..	199
5	..	311
6	..	93
7	..	17
8	...	9

A curve showing the frequency distribution of the branching character among the plants in a normal field of *kumpta* cotton at Dharwar is shown below (Fig. 3).

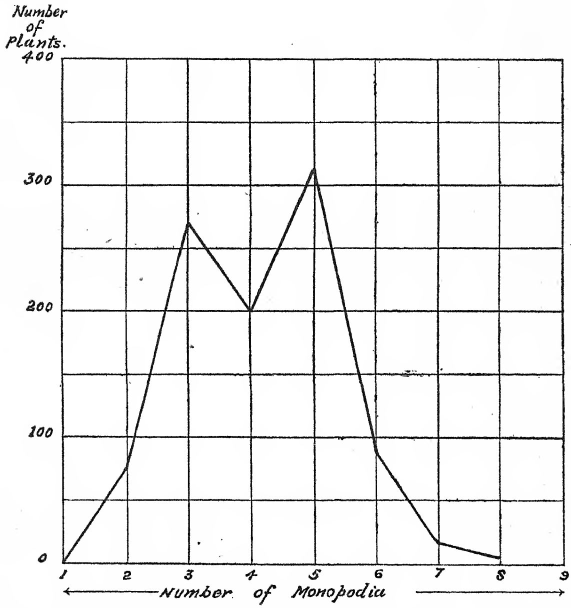


FIG. 3.

The curve, it will be seen, shows two points of very great frequency, one where the plants have three monopodia, the other where there are five, the latter being a little the more common. The mean number of monopodia is 4·15.

Such a multimodal curve means in this case, probably, that there are a number of different strains of cotton intermixed, with different tendencies to form monopodia. This probability is made almost into a certainty by a consideration of the variation in other characters.

(2) *The shape of the lobes of the leaf.* The lobing of the leaves is often regarded as a useful character in classifying cottons, and in most descriptions of species and varieties the shape and size of the lobes is usually referred to. Leake[1] was the first, however, to introduce any system of recording this character by measurement, and his 'leaf factor' was intended to supply the necessary accurate expression of the depth of the leaf indentations combined with the width of the lobes. It consisted in the maximum length of the leaf from the tip of the central leaf lobe to the base of the petiole (l), minus the distance from the bottom of the adjoining indentation to the base of the petiole (l^1), divided by the maximum breadth of the central lobe (b). It is indicated, in fact, by the expression $\frac{l - l^1}{b}$. This, as Leake remarks, is a purely empirical figure, but nevertheless, affords a useful means of indicating the shape of the leaf. I have obtained almost the same figure by simply measuring the length of the central lobe of the leaf and dividing it by the maximum breadth of the lobe.

Certain precautions are obviously necessary in the case of all such measurements. A primary leaf on the main stem differs much from the secondary leaf on the branches of the same plant. The primary leaves on any one plant, however, vary very little with the exception of the first three. These are in many cases abnormal, showing a smaller number of divisions than the remaining leaves on the plant. To secure uniformity of method, however, all measurements were taken on the sixth, seventh, or eighth leaf from the base of the stem.

Before giving the actual figures obtained in measuring the length and breadth of the middle lobes of such leaves of *kumpta* cotton, I may say that a simple experiment in crossing between two pure lines, breeding true, which I had isolated, indicates that in the length and breadth of the lobes of the leaf we are dealing with two simple Mendelian factors. It was found, in

[1] *Journal of the Asiatic Society of Bengal*, Vol. IV, No. 1 ; *Journal of Genetics*, Vol. I, No. 3.

fact, that a long middle lobe is dominant over a short one, and a broad lobe is dominant over a narrow one. A strain bearing leaves with long and narrow lobes was crossed with another bearing short and broad lobes. In the F_1 generation all the plants had long and broad lobes. In the F_2 generation a splitting occurred, giving plants in the proportion of twenty-seven plants with long and broad lobed leaves, nine plants with long and narrow lobes, nine plants with long and broad lobes, and three plants with short and broad lobes. This would seem to suggest the unwisdom of combining the measurements of length and breadth into one factor. I, therefore, submit the actual measurements of leaves (selected as above described) from one thousand plants in one field, grown under identical conditions of climate, soil, manure and cultivation.

Breadth of central leaf lobe.

Breadth of central lobe in millimeters		Number of times occurring ("Frequency")
27 — 30	....	61
30 — 33	....	198
33 — 36	....	271
36 — 39	....	252
39 — 42	....	128
42 — 45	....	71
Over 45	....	19
	Total ..	1,000

Length of central leaf lobe.

Length of central lobe in millimeters	....	Number of times occurring ("Frequency")
39 — 42	....	22
42 — 45	....	21
45 — 48	....	77
48 — 51	....	250
51 — 54	....	158
54 — 57	....	222
57 — 60	....	120
60 — 63	....	62
63 — 66	....	9
Over 66	....	39
	Total ..	1,000

Curves showing the frequency distribution of the various breadths and lengths of the central leaf lobe among the plants in a normal field of *kumpta* cotton at Dharwar are shown below (Fig. 4).

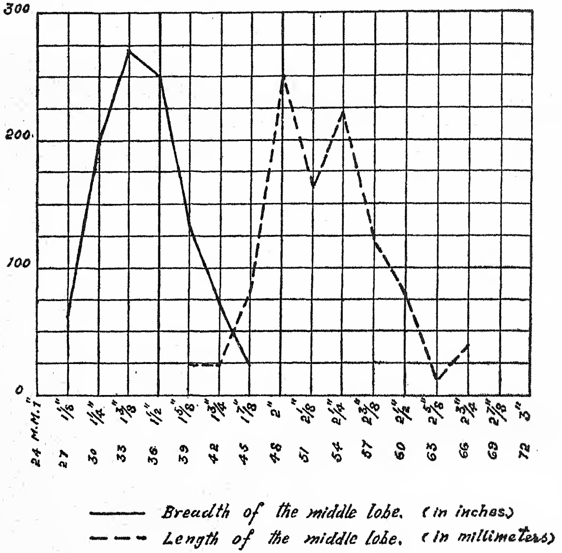


FIG. 4.

The mean breadth of the central lobe is 34 mm., the mean length is 52 mm.*

The curve of length is multimodal. The curve of breadth is also, in all probability, not simple. These, therefore, confirm the conclusion previously derived from a consideration of the branching that we have not a single varying type, but a mixture of several strains with differing characters in this respect. The figures, however, show the extent of variation in these factors which may be expected in *kumpta* cotton grown under identical conditions.

(3) *The shape of the bracteole.* So far as a preliminary study by crossing can indicate, the bracteole behaves very similarly to the middle lobe of the leaf, and the length and breadth of the bracteole seem to behave as simple

* I count in each case the lower width or length in each group of measurement as typical of that group.

Mendelian factors. A long bracteole is, in fact, dominant over a short, and a broad one is dominant over a narrow one. The number of teeth, and their arrangement and incision varies much on the same plant. The teeth vary from four to eight, and there is often some difficulty in finding out the rudimentary projections, which have to be separately counted. It is hoped to study the variation of these bracteole characters further, now that pure lines have been obtained, and have been crossed.

The variation in the length and breadth of the bracteole of open flowers on different *kumpta* plants is as follows :—

Length and breadth of bracteoles.

	"FREQUENCY"	
Millimeters	Length of bracteole	Breadth of bracteole
12 — 15	31	110
15 — 18	278	382
18 — 21	190	408
21 — 24	391	99
24 — 27	78	..
Over 27	32	..

The attached frequency curve (Fig. 5) shows that the extent of variation is not very wide. The mean length of the bracteole is 18·9 mm., the mean breadth is 16·5 mm.

Again the curve of length of the bracteole is multimodal, and that of the breadth shows evidence that it might also be so in reality. The conclusion from this is again in accordance with what has been noted for the previous factors measured.

(4) *The flower characters.* Perhaps the two most important characters in the cotton flower, from a breeding point of view, are the length of the petals, and the length of the style. The petals may be, in extreme cases, small and almost closed in the folds of the bracteoles, or they may be large and very prominent. In *kumpta* cotton, however, they are always large, showing only a small amount of variation.

The length of the style, likewise, varies much in different varieties, and in the extreme case of some tree cottons, it projects over an inch above the staminal column—in which case the chance of cross-pollination is very great. The stigma of the soft Peruvian tree cottons may often be seen without a single grain of pollen on it for a long time after the opening of the petals. It is probably on this account that no two plants of this variety agree in their characters, and the variation is very great. A short style will, on the other

hand, probably diminish the amount of natural crossing by securing fertilization as soon as the anthers burst open.[1]

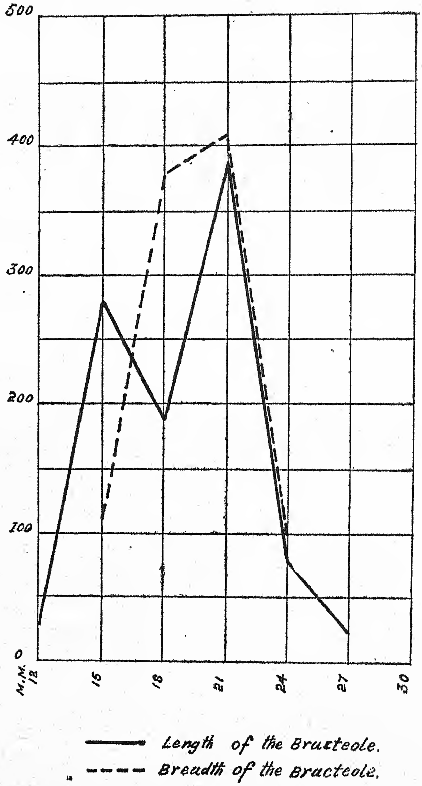


FIG. 5.

[1] Lawrence Balls ("Cotton Plant in Egypt," pp. 118-119) has studied this subject in some detail, but his conclusions that the length of the style is a minor factor in natural crossing probably requires to be revised under different conditions.

The range of variation of the above flower characters is shown by the following figures based on one thousand flowers :—

(a) Length of petals.

Millimeters		Frequency
12 — 15	....	159
15 — 18	....	142
18 — 21	....	229
21 — 24	....	320
24 — 27	....	121
Over 27	....	29

Here again we have a very wide variation and clear illustrations of a mixture of strains with different lengths of petals. The mean length is 18·6 millimeters, but with such a mixture of strains the mean ceases to have much value. The interesting figures would be the correlation between the length of the petals and of the bracteoles, and this will be determined in a further study of this question. A curve embodying the above figures is shown below (Figs. 6 and 7).

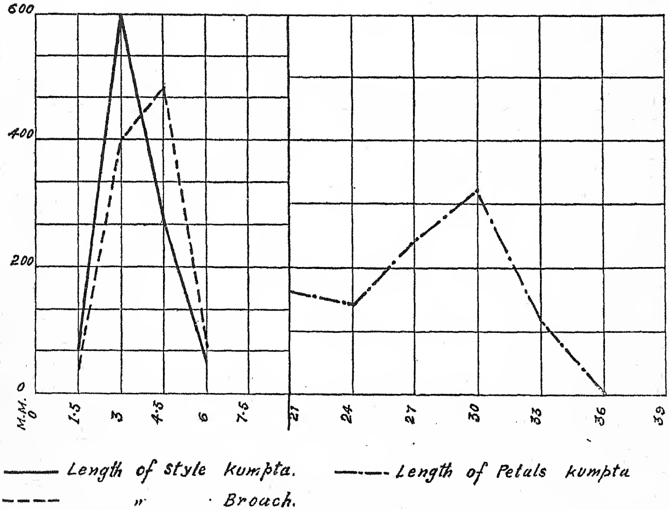


FIG. 7 FIG. 6.

(*b*) *Length of style.* The measurement taken was that of the projection of the style beyond the central column, in the flowers of *kumpta* cotton, and these figures are taken from a thousand examples.—

Millimeters		Frequency
1·5 — 3·0	....	48
3·0 — 4·5	....	402
4·5 — 6·0	....	479
Over 6·0	....	71

Here there appears to be less variation than in most of the previous characters studied. If we count the curve as a simple one then the standard deviation is seen to be 1·043 and the co-efficient of variability 0·274. The mean length of the style beyond the central column is 3·86 millimeters.

(5) *The boll characters.* I have already described the *kumpta* cotton as one bearing small bolls, with a tapering beak. The size and shape are subject to variation like other characters, not only on different plants, but on the same individual. The variations from the normal are widest during the last stage of growth, when the plants generally suffer from heat and drought. So far I have not been able to devise numerical expressions for denoting these variations, but they deserve careful study.

The other characters which are important are the number of cells in each boll, and the number of ovules in each cell. With regard to the number of cells in the boll, the number varies from two to six, although a greater range is possible. The actual variation is, however, very slight indeed in *kumpta* cotton, nearly all the bolls examined containing three cells. The following table shows the frequency of the various numbers of cells in 1,000 bolls examined :—

Number of cells		Frequency
2	....	2
3	....	987
4	....	11
	Total ..	1,000

I may note here that this constancy is not so great with other types of Indian cotton. In the well-known "N. R." variety of *Gossypium neglectum*, while the predominant number of cells per boll was still three, there was a larger number of bolls with four cells, the proportion being 160 in one thousand

bolls. The condition for *kumpta* and for "N. R." cotton is shown in the following curve (Fig. 8).

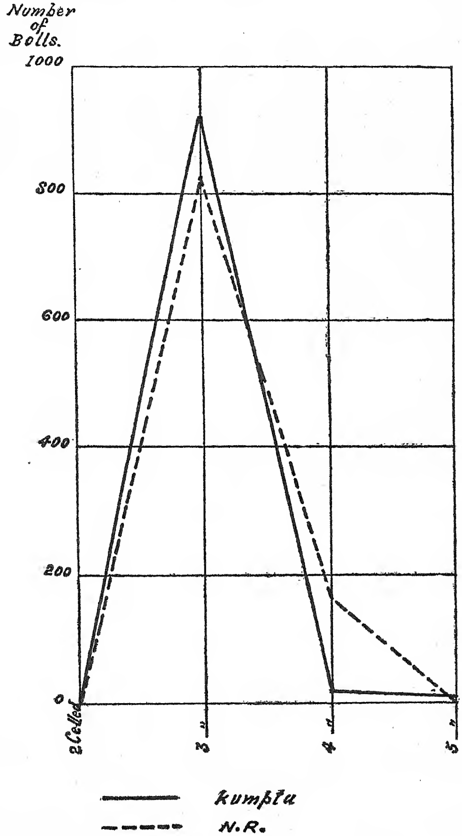


FIG. 8.

It may be here noted that among all Indian-grown cottons that I have examined, except acclimatized American and Cambodia, the three-celled boll is predominant. Among American varieties belonging to *Gossypium hirsutum* four to five-celled bolls are the most common.

The number of ovules in the cell varies from five to eight and this character is somewhat variable. The most common number is seven, which occurs in about sixty per cent. of the cases. Few cells (about 4 per cent.) contain five ovules. Still fewer (about one per cent.) contain eight ovules. The ovules are arranged one above the other in two rows. These rows contain four and three when there are seven ovules in the cell, contain four and two or three and three when there are six ovules in the cell, and contain three and two when there are five ovules. The cells containing eight ovules often show a different arrangement, into three rows containing 4, 3 and 1 or 4, 1 and 3. These arrangements are illustrated in the figure below (Fig. 9).

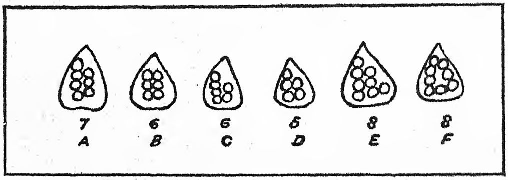


FIG. 9.

The actual frequency of each number in one hundred examples is shown by the following figures :—

Number of ovules per cell		Frequency
5	....	4
6	....	35
7	....	60
8	....	1
	Total ..	100

The importance, from the point of view of yield, of the number of ovules per cell of the boll is hardly capable of being appreciated on the present data. At first sight it would seem that a large number of ovules per cell will probably mean a big boll and large yield. Whether this is so, will be a matter for further study.

(6) *Ginning percentage.* Among the most important characters in determining the suitability of a cotton for cultivation is the ginning percentage,

that is to say, the proportion of lint to seed cotton. I have already said that *kumpta* cotton on the average has a very low ginning percentage, but the actual figures vary very widely within the type of cotton. Some plants give as low a percentage as 18, others as high as 30. The average is usually considered to lie about 26, but in one hundred plants taken at random on the Dharwar farm the mean percentage was 23·6. The actual figures were as follows :—

Ginning percentage		Frequency
18	....	1
19	....	2
20	....	9
21	....	12
22	....	19
23	....	11
24	....	14
25	....	9
26	....	6
27	....	7
28	....	1
29	....	8
30	....	1

The curve which follows (Fig. 10) illustrates still more clearly the very wide variation.

Of course it must always be recognized that the ginning percentage is the product of a complex of factors, including season, climate, soil, and luxuriance of plant, and that the variety or strain is only one of these factors. But when plants are grown under identical conditions in the same field, a curve like that shown below can hardly be due to anything except a complicated mixture of strains yielding cotton of widely different ginning capacity.

(7) *Seed weight.* The weight of the seed is an important character in cotton, as it has a bearing on the yield and ginning percentage. Cooke[1] points out that lighter seeds raise the percentage of lint, as is indeed obvious, and at first sight it would suggest that the aim of a cotton-breeder should be to reduce the seed weight. But the evidence at present in hand seems to indicate[1] that there is a high positive correlation between the seed weight and lint weight. Though this statement needs confirmation as applied to Indian cottons in general and to *Gossypium herbaceum* in particular, yet, in the meantime, considerable interest attaches to the variation in the seed weight of the cotton we are studying.

[1] Cooke. *U. S. A. Bureau of Plant Industry, Circular No. 11.* Balls, L. "Cotton Plant in Egypt," pp. 86 and 101.

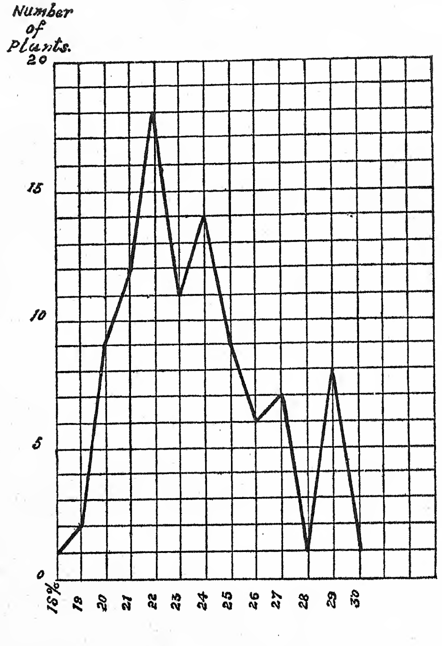


FIG. 10.

The variation in weight of 1,000 seeds from a single field, the cotton hence being grown under identical conditions, is shown in the following figures :—

Seed weight in grams		Frequency
0·025	...	10
0·030	....	29
0·035	....	9
0·040	....	11
0·045	....	32
0·050	....	172
0·055	....	410
0·060	....	101
0·065	....	118
0·070	....	42
0·075	....	39
0·080	....	20

The average weight per seed is 0·055 gram, and this is identical with the mode. The variation is very wide. If we may consider this array as simple, then the standard deviation would be 0·0028, and the co-efficient of variability 0·051. The variability is hence very high. I propose to study the correlation between the lint percentage and seed weight, and so determine whether the conclusions of Balls in Egypt in this matter are valid for *kumpta* cotton. The attached curve (Fig. 11) illustrates the variability of the seed weight.

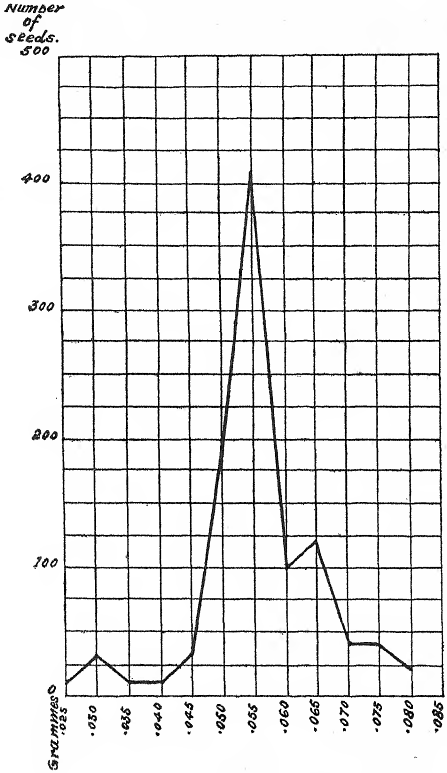
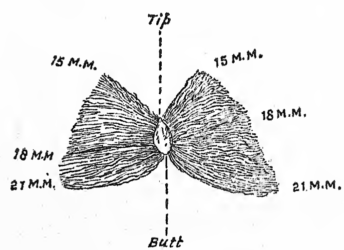


FIG. 11.

(8) *The staple.* The lint of *kumpta* cotton is markedly variable in staple and in strength. The length of the lint may be anything from half an inch to one inch, and the strength from very weak to strong. The variation in the length of staple has been studied on seed cotton, and the method is that used by Balls.[1] Seven seeds of each plant were combed and the length of fibres coming from the middle portion of the seed measured. Generally, the tip of the seed bears short hairs and the butt end bears long ones. The difference between the length at the tip and the butt of the same seed is often as great as six millimeters ($\frac{1}{4}$ inch). This is illustrated in Fig. 12.



Arrangement of Lint on seed

FIG. 12.

The bulk of the fibres are, however, placed between the two ends, and the measurement taken in the middle of the seed represents the mode of the length. Such a measurement is taken seven times in the case of each plant, and the mean of these is adopted as the length of the staple of that plant. One more precaution is also taken. The seeds placed at the apex of the cells of the boll produce shorter hairs than those of other seeds of the same boll. This difference is marked in the late bolls which form the bulk of the last picking. All such seeds were excluded from the above measurements.[2]

[1] "The Development of Raw Cotton," page 184.

[2] It is possible that differences in staple may exist between the cotton lint from bolls produced in the different classes of branches. This matter is now under study.

Two hundred plants taken at random from the same field were examined and the results are shown in the following table :—

Length of staple Inches		Frequency
0·5	....	16
0·6	....	44
0·7	....	56
0·8	....	54
0·9	....	24
1·0	....	6

These figures show very wide variation. The mean is 0·722 inches, but figures distinctly lower than this are more common than those much higher. The standard deviation is 1·10 and the co-efficient of varilabiity is 1·57. As the length and the uniformity of the staple is one of the most important features in determining the value of a cotton it shows what a large field there is for improvement in both respects on an average *kumpta* cotton as now grown.

The attached curve (Fig. 13) illustrates the variation occurring in the staple of *kumpta* cotton.

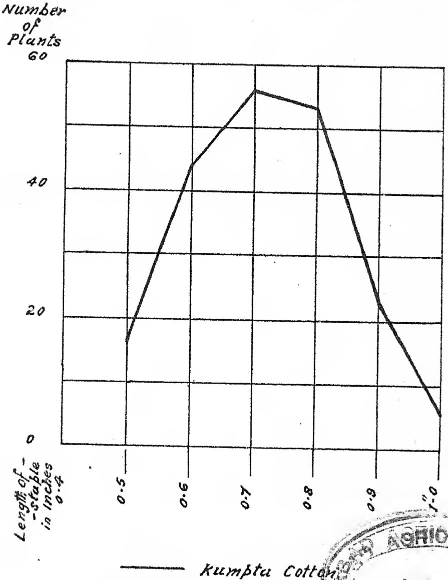


FIG. 13.

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This study of the variation in a type of cotton, said to possess very stable characteristics, leads one to the conclusion that the stability of *kumpta* cotton, as ordinarily grown, has been much exaggerated. The numbers obtained, furthermore, make it almost certain that the variability noticed is due not to the ordinary variation in a single strain, but to the mixture of a number of strains. Take the ginning percentage, for example, and it will at once be seen that the curve obtained has four separate modes at 22, 24, 27 and 29—and the frequency curves representing other characters are in many cases also multimodal. Such multimodal curves inevitably suggest mixture, and in certain cases[1] it has been proved that they are due to the co-mingling of several different local races of a species.

If this is the case, the first step towards improvement will obviously be to determine the type or types which have the highest value to the grower, ginner, and buyer of cotton, select those strains of plants which most nearly conform to the various requirements, see whether these, when self-fertilized, breed true, and when they do so, to multiply them and gradually replace the present indefinite mixture of strains of very different economic value by one which combines the greatest number of desirable characters. The next chapter gives the result of a study of what is likely to be an ideal type of cotton for the *kumpta* tract.

V. Ideal type of cotton for the "kumpta" tract.

Yield. The type of cotton best suited for a tract must be greatly determined by the yield. The latter, therefore, must play an important part in all our considerations. The part which directly yields cotton is the boll. Consequently all gain in yield can only be secured by improvements in the boll. It is obvious that if nine bolls on each plant produce an yield of five hundred pounds of seed cotton to an acre, ten bolls on each plant will certainly increase the outturn by fifty pounds. Great attention must thus be paid to increase the number of bolls with the object of getting better yields.

Cotton plants vary very widely as regards their number of bolls. But the variations, though intrinsic, are greatly controlled by external influences. Individuals enjoying a slight advantage of plant food, moisture, or space, by virtue of their position, bear a greater number of bolls than their neighbours less favourably located. This, however, can be tested and the selections which owe their superiority to environment only can be rejected. The matter is, however, important, for, if the conditions on the testing plots are different (as

[1] De Vries. Ueber Curven—" Selection bei Chrysanthemum segetum." *Ber d, deutsch., Bot. Ges.*, Vol. XVII, p. 86.

is often the case) from those of the fields where the trial is to be ultimately made, even the tested strains may disappoint us altogether. Under such circumstances any one engaged in selection is likely to be deceived by the wrong forms and labour under misconceptions to no purpose.

To avoid all this trouble one must not be entirely guided by the number of bolls. This character, however, is often found intimately associated with others which are not influenced by environment to anything like the same extent. The study of such correlations, therefore, is very important and useful.

All annual cottons produce from the lower portion of their central stalk woody stems or limbs (monopodia). These vary in number and vigour in different varieties. The remaining portion of the central stalk bears at each node a small zigzag branch which directly supports the bolls (sympodia). At the base of these branches two vegetative shoots also appear, though somewhat rarely, which, like the monopodia above mentioned, branch before they bear the reproductive organs. We have thus three kinds of branches: (1) limbs or monopodia, (2) fruiting branches (sympodia), (3) axillary vegetative shoots. When all these three are present, the fruiting branches flower first, then the limbs, and lastly the axillary vegetative shoots. The limbs and axillaries thus prolong the period of flowering. Their extensive development very often causes the suppression of the fruiting branches, in which case the flowering also starts late. This is not, of course, necessarily a drawback, but in practice it is found that their extensive development in *kumpta* cotton exerts an injurious influence on the number of bolls, which is all important. The fruiting branches coming from the central stalk are in all cottons most productive. Those on the vegetative branches produce a large number of flowers but very few bolls. The following statement shows the productive capacity of the fruiting branches, limbs (monopodia) and axillaries in three types of *Gossypium herbaceum*:—

	Fruiting branch		Limb		Axillary	
Name	Average length of a branch	Average number of bolls on each	Average length of a branch	Average number of bolls on each	Average length of a branch	Average number of bolls on each
	Inches		Inches		Inches	
Kumpta, erect ..	2·31	1·11	13·01	0·50	6·01	0·02
Kumpta, bushy ..	1·63	0·74	17·21	0·32	11·42	0·07
Broach	1·02	0·48	21·81	0·53	14·71	0·18

From this table it will be noticed that one inch length of each type of branch carried the following number of bolls :—

Name	Number of bolls per one inch of branch		
	Fruiting branch	Limb	Axillary
1. *Kumpta*, erect ..	0·48	0·038	0·003
2. *Kumpta*, bushy ..	0·45	0·019	0·006
3. *Broach*	0·47	0·024	0·012

It is thus obvious that expenditure of energy in growing long limbs or axillaries in all three types is largely wasted, and that if a strain of equal vigour can be found which expends its energy in growing fruiting branches rather than limbs and axillaries, it will probably be a much higher yielding type of plant.

In the case of *broach* cotton the fruiting branches are greatly smothered by the vigorously growing limbs and axillaries, and this fact can be experimentally proved by removing the latter as soon as they appear, when the fruiting branches show marked increase in vigour and bearing. This effect is also clearly seen in early and late sown *broach* cotton at Dharwar. When the sowing is done early (in July) *broach* cotton becomes very vegetative, bearing weak and insignificant fruiting branches. If, however, the sowing is done late (in August) the rank growth is greatly checked and the fruiting branches show themselves well. The extravagance of the vegetative branches in the case of other cottons is marked on heavily manured fields where the plants yield very little in proportion to their size.

The fruiting branches, therefore, unless smothered or suppressed, yield a larger number of bolls than other parts. They also produce bigger bolls in many cases. In *kumpta* cotton I have found that nine bolls on the fruiting branches are normally equal to ten on the limbs and twelve on the axillaries. For these reasons our efforts to augment the outturn should, it would seem, be directed towards curtailing the vegetative growth and increasing the number of fruiting branches per acre, if this can be done without decreasing the general vigour of the plant. This, it would seem likely, might be done by growing an erect type as thick as it will conveniently stand. The individual plants of this type may not look as prolific as those of the bushy type when the latter have ample space. But the comparison which has always to be made is not in the yield per plant, but in the yield per acre. And hence in all such comparisons a row of plants sufficiently long must be taken as a unit.

Earliness. The cottons growing in the *kumpta* tract have, for *herbaceum* cottons, a relatively short growing period. They are sown at the end of August and their actual increase in size almost stops at the commencement of the cold weather in November. They further receive a check in March when the flowering suddenly ceases. Under these conditions the type best suited should be quick in growing and early in flowering. The ante-monsoon showers falling in the months of April and May often spoil the later pickings. If the cotton, however, can be completely collected in two pickings the danger is greatly minimized.

In short, the plant which grows quickly, bears only fruiting branches, flowers early, and finishes its yield at the most in two pickings, is the ideal one for the *kumpta* tract, and it should be our endeavour to select such a type from the numerous strains found in the ordinary *kumpta* cotton, which, while possessing these characters, also gives cotton of staple and ginning percentage at least as high, if not higher, than that of the mixture now grown.

VI. Selections from "kumpta" cotton.

Having thus laid down (*see* previous chapter) the type of cotton plant which is likely to give a large yield of cotton, the problem of improvement might at first sight appear comparatively easy. But in cotton it is very often found that high-yielding types are not the most profitable to grow owing to their deficiencies in other directions. In fact it has been supposed by some that there is a natural antagonism between high yield, high-ginning percentage, and long staple. Though our results among *herbaceum* cottons do not entirely justify this position, yet the combination of these three qualities in one strain of cotton plant is very rare. It is even rare to find high-ginning percentage and long staple combined in the produce of one cotton plant. High-ginning percentage is more frequently combined with high yield in one and the same plant, and likewise long staple is not uncommonly found in a strain whose yield is high. If high-ginning percentage is obtained at the cost of staple, the result is not at all desirable at least among *kumpta* cottons, for this tract is capable of yielding cotton of good staple and enjoys peculiar advantages for growing it. A type which gives a high yield and also has a long staple has, therefore, a better chance of success than any other, and it was to finding a type of this sort that our efforts were primarily directed.

We have, as a result of efforts to get as near as possible to the ideal type of cotton plant described in the previous chapter, and keeping in view the primary necessity of a high yield of a long staple cotton, now obtained three fixed strains of cotton by selection from the *kumpta* cotton grown at Dharwar, all of which have bred true through several generations. Each of these has advantages over the ordinary mixed type locally grown, and I will describe the origin and characters of each of these selected types.

"Dharwar No. 1."

The first of these selected strains, which I have termed "Dharwar No. 1," (Pl. IV, fig. 1) is a selection from the erect plants of ordinary *kumpta* cotton, made because it conforms very largely to the ideal type I have described, in that it bears very few limbs (monopodia) and axillary vegetative branches. The attached frequency curve (Fig. 14) shows the difference in the number of limbs (monopodia) as compared with those on an ordinary mixed lot of *kumpta* cotton.

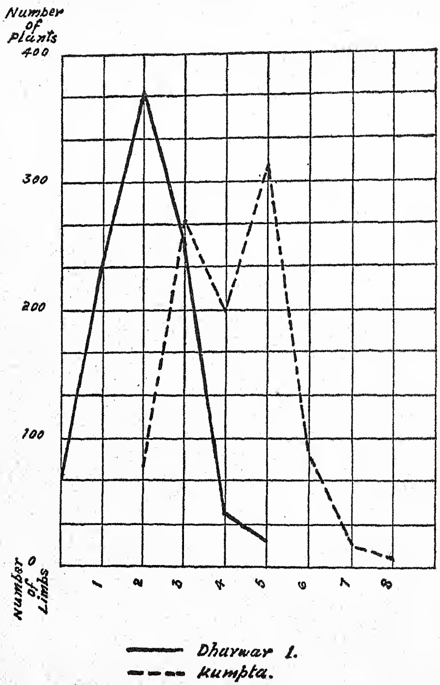


FIG. 14.

The difference is obvious. We have in this strain one with very much smaller number of monopodia and, moreover, one whose variability is very

PLATE IV.

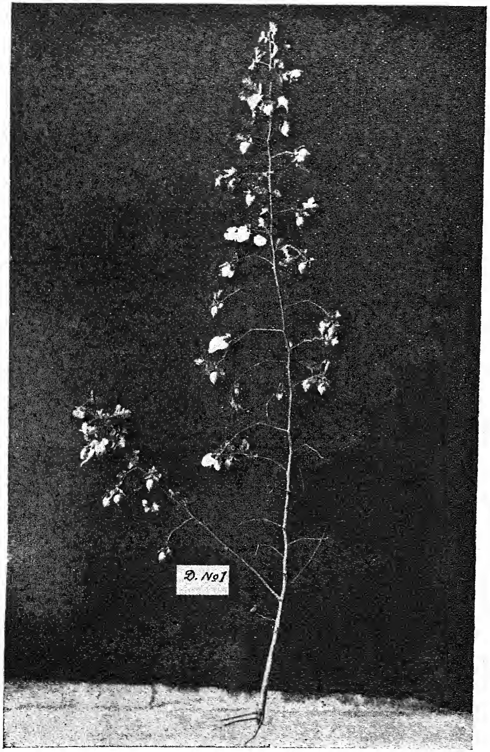


Fig. 1. Typical plant of "Dharwar No. 1" Cotton.

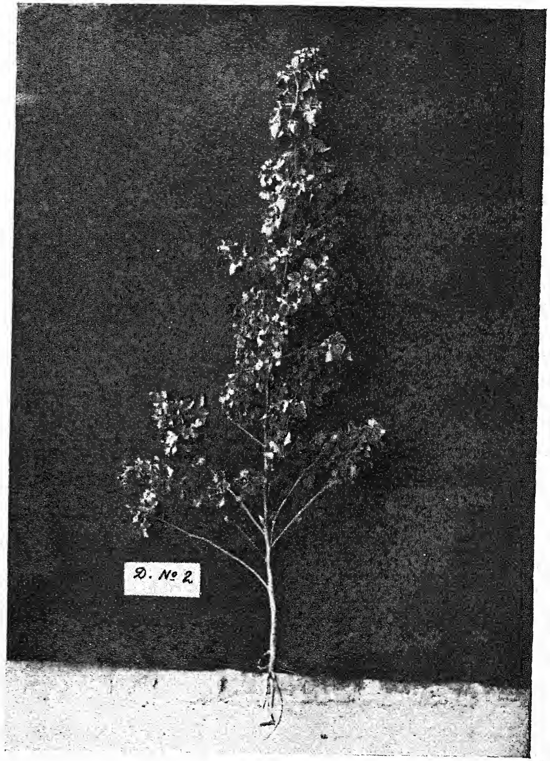


Fig. 2. Typical plant of "Dharwar No. 2" Cotton.

much reduced. The character of the curve suggests that it is simple, and that the array is a homogeneous one.

The next point about this selection is its earliness. Not only does it, as would be expected, in the absence of many limbs, produce the greater part of its bolls in fruiting branches or sympodia, but these fruiting branches tend to appear early. The first of these fruiting branches appears, usually, at Dharwar, at the seventh or eighth node about eight inches from the ground, and the appearance of these branches is followed by rapid flowering. The accompanying curve (Fig. 15) showing the number of flowers on one hundred

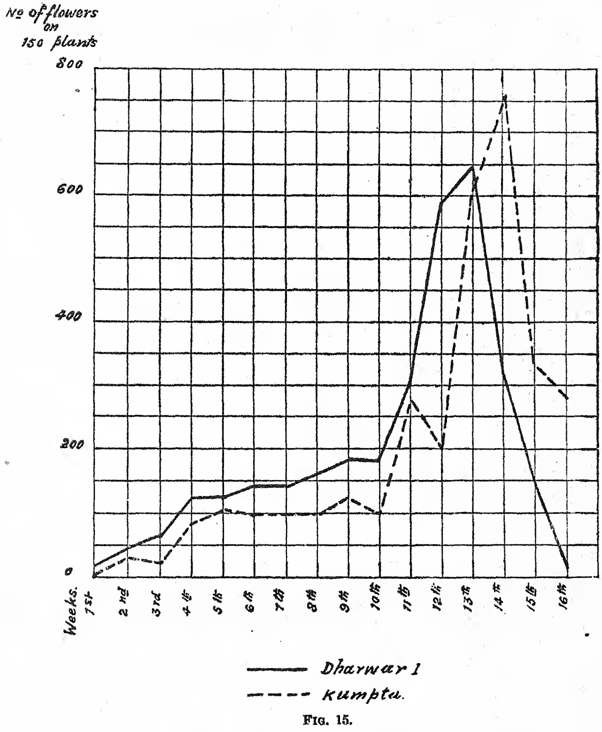


FIG. 15.

and fifty plants at various times after planting, as compared with those on a similar number of ordinary *kumpta* plants, illustrates this point.

Here it will be seen that while the cottons commence flowering at the same time, the number of flowers on the "Dharwar No. 1" is considerably higher, though the general course is the same. After the tenth week the "Dharwar No. 1" shows a rapid rise and reaches its maximum in the thirteenth week, and then rapidly falls, while flowers practically cease to appear after the sixteenth week. The ordinary *kumpta* cotton in cultivation reaches its maximum a week later than the selection under discussion, and then the fall is not so rapid. Flowers are, in fact, still being produced in large numbers in the sixteenth week, and afterwards. While, therefore, the "Dharwar No. 1" strain of cotton produces nearly all its flowers from the tenth to the fifteenth week, the *kumpta* as ordinarily grown goes on from the eleventh week until long after the sixteenth week, and, in fact, has a tendency to produce a very considerable proportion of its flowers in the latter part of its growing season.

This tendency to produce a large proportion of late flowers is a special disadvantage because, as the following table shows, the later the flowers are produced the greater the percentage of them which are shed and never develop into bolls. The figures were obtained by marking a large number of flowers which appeared during the months of December, January, February and March, and watching their later development both in the "Dharwar No. 1" and the ordinary *kumpta* cotton.

Month	"Dharwar No. 1"		"Kumpta" ordinary	
	Number of flowers marked	Percentage of flowers shed	Number of flowers marked	Percentage of flowers shed
December	120	16·7	190	52·7
January	2,370	14·8	2,500	36·0
February	2,480	69·0	5.210	79·9
March	50	100·0	20	100·0

These figures show the enormous increase in the wastage of flowers formed after January. Of flowers formed in March, in both cases none form bolls. They also show the very much larger proportion of flowers shed without forming bolls in the ordinary *kumpta* cotton than in the "Dharwar No. 1."

Another experiment to compare the proportion of flowers to bolls during 1917-18 and 1918-19 in the "Dharwar No. 1" and in ordinary *kumpta* cotton gave results shown in the following table :—

Name of cotton	1917–1918			1918–1919		
	No. of flowers on 100 plants	No. of bolls on 100 plants	Percentage of bolls to flowers	No. of flowers on 100 plants	No. of bolls on 100 plants	Percentage of bolls to flowers
"Dharwar No. 1" ..	2,332	1,562	67·0	2,800	1,921	68·6
Kumpta, ordinary ..	3,751	1,537	41·0	4,655	1,898	39·6

The ordinary *kumpta* cotton thus produces fifty per cent. more flowers than "Dharwar No. 1" when grown at Dharwar, but ripens a smaller number of bolls per plant. The number of bolls ripened is not, however, markedly greater, owing to the fact that the wider spacing (24 inches by 18 inches) adopted for the sake of the more bushy types mixed in the *kumpta* ordinary cotton was a positive disadvantage for the erect "Dharwar No. 1."

The "Dharwar No. 1" strain having been found to breed true to type has been tested every year since 1914 at Dharwar to ascertain its yielding capacity as against the ordinary *kumpta* cotton of the farms. The results have been as follows :—

Year	Yield of *kapas* per acre		Percentage increase given by "Dharwar No 1"
	"Dharwar No. 1"	*Kumpta*	
	lb.	lb.	
1914	620	542	14·3
1915	612	564	8·5
1916	390	310	22·2
1917	547	440	24·5
1918	648	480	35·0
Average	563	467	20·9

"Dharwar No. 1" thus yields, on the average of five years, 20 per cent. more *kapas* per acre than ordinary *kumpta*. This increase in itself may or may not mean a corresponding gain in the nett profit. Whether it does so or not, depends on whether the increase in yield is accompanied by an equal

or larger ginning percentages, and by an equal or larger staple and equal strength and character of fibre. It is necessary, therefore, to determine how the selection compares with the ordinary *kumpta* cotton in these directions.

So far as the ginning percentage is concerned the comparison is given below :—

Year	Ginning percentage		Percentage increase given by "Dharwar No. 1"
	"Dharwar No. 1"	*Kumpta*	
1914 ..	29·0	26·0	11·5
1915	28·0	26·0	7·8
1916	28·8	26·0	10·7
1917	28·0	24·7	13·3
1918	29·1	25·2	15·4
Average ..	28·5	25·5	11·7

The increase in ginning percentage is not very large, but it is distinct. Further it is observed that the ginning percentage of the "Dharwar No. 1" has remained very constant. Most of the samples either grown by myself or grown by others have ginned between 28 and 29 per cent. of cotton lint. This constancy of ginning percentage enhances the commercial value of the *kapas* of "Dharwar No. 1," for normally the ginning percentage of *kumpta* cotton varies a good deal.

The comparative constancy of the ginning percentage is shown by the following figures intended to show the variability of different plants in this character :—

Number of plants examined	100 plants
Ginning percentage 26	3 ,,
,, ,, 27	18 ,,
,, ,, 28	56 ,,
,, ,, 29	12 ,,
,, ,, 30	10 ,,
,, ,, 31	1 ,,

The distribution is shown in the attached curve (Fig. 16), which may be compared with that for the *kumpta* crop in general shown in Fig. 10.

The average ginning percentage is 28·1 which is identical with the mode. The variation is narrow. The standard deviation is 0·301 and the co-efficient of variability is 0·0107.

This gain in ginning percentage may be due to a greater development of lint or to a decrease in the weight of the seed. It is not, however, due to

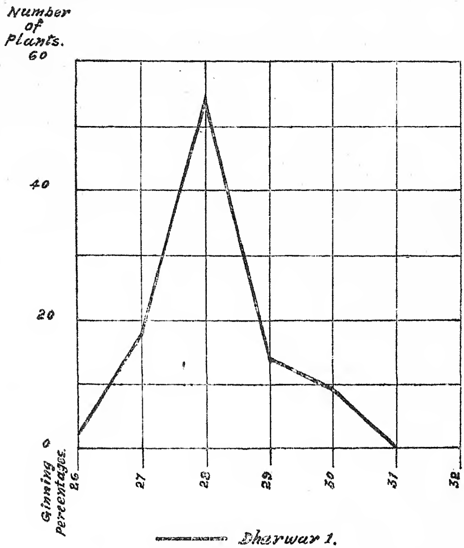


FIG. 16.

the latter cause—a decrease in the weight of the seeds—for the following table shows that the seeds have, each year, been slightly heavier than those of the ordinary *kumpta* crop grown on the same farm :—

Year	Weight of 100 seeds	
	"Dharwar No. 1"	*Kumpta*
	Grammes	Grammes
1916	5·320	5·070
1917	5·730	5·307
1918	5·480	5·210

Perhaps the chief interest in the present selection, "Dharwar No. 1," is in its staple, for it is the final result of selection originally started in *kumpta* cotton in 1904, specially with the view of improving the staple. For the first six years all plants carrying good staple were taken collectively, but in

1910 the mass selection was discontinued and unit selection from the plants which appeared to have the largest combination of useful properties, and which bred true to type when self-fertilized, was adopted. In 1912 the erect strains of *kumpta* were found to be superior in yield to the bushy type and selection was principally continued chiefly with this type. The main object was still the selection of the best staple cotton from the ordinary *kumpta*, but attention now was also directed to the ginning outturn. The final selection of "Dharwar No. 1" was made in 1913, as the type seemed to possess a combination of erect character of plant, high yield, high-ginning percentage, and good staple.

One of the special features of value in "Dharwar No. 1" is the evenness of the staple. The length of the cotton fibres on the seeds of two hundred plants was determined by the method described on page 248 and the following are the results :—

Total number of plants examined	200
Staple of 0·7 inch	0 plants
" " 0·8 "	24 "
" " 0·9 "	72 "
" " 1·0 "	84 "
" " 1·1 "	20 "

The attached frequency curve (Fig. 17) shows the position, and should be compared with the curve for ordinary *kumpta* shown on page 249 (Fig. 13).

The mean is 0·95. The standard deviation and the co-efficient of variability are 0·0306 and 0·034 respectively.

The staple of the "Dharwar No. 1" has remained ever since distinctly higher than the ordinary *kumpta* cotton, and its strength is also good. The staple measures about one inch, and is, of course, more uniform. The following are valuations and remarks very kindly made by the valuers of Messrs. Tata and Sons, Bombay, for each year from 1914 to 1918.

Year	Value of lint per candy of 784 lb.		Remarks of valuers
	"Dharwar No. 1"	*Kumpta*	
	Rs.	Rs.	
1914	245	230	In every respect "Dharwar No 1" is superior to *kumpta*.
1915	350	335	Silky and better than *kumpta*, all round. Will spin up to "35."
1916	550	530	Better than *kumpta* in every respect, in cleanliness, in length and in strength of fibre.
1917 ..	950	900	Nice stapled cotton. Value equivalent to *surat*.
1918	640	625	Is decidedly superior in length of staple to ordinary *kumpta*.

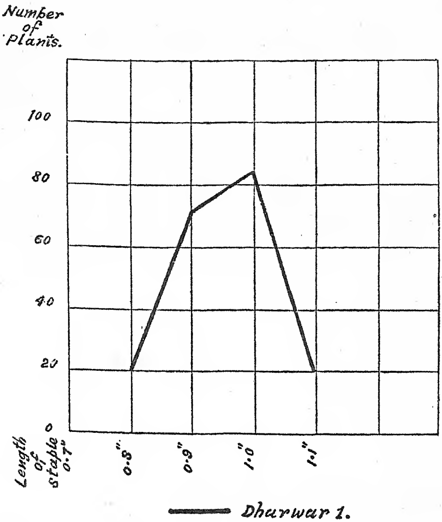


FIG. 17.

The 1918 cotton was submitted to the Cotton Contracts Board, Bombay, and their opinion, very kindly furnished, is as follows:—"The sample in spite of some nappiness and want of silkiness is a very excellent cotton which if it continues to maintain its present characteristics and its superiority in yield should have a great future before it. As compared with good *kumpta* the sample is fine and possesses an excellent strong staple. It is valued at Rs. 30 to 40 per *candy* better than good *kumpta*."

We have thus a cotton which yields better, gins higher, and possesses a staple which is larger and stronger than the ordinary *kumpta*, and is, therefore, desirable in every way. It has now spread over 1,000 acres (in 1918), and is being distributed to an area of 6,000 acres in the *kumpta* area (in 1919). The characters are being maintained by fresh selection from protected and self-fertilized plants every year, and it seems probable that it will have a considerable future in the area now growing *kumpta* cotton.

"*Dharwar No. 2.*"

While from the point of view of general improvement of *kumpta* cotton, "Dharwar No. 1," as already described, may be considered to possess the best combination of characters yet discussed, it may be of value to describe shortly certain other strains which have been isolated and kept pure for a number of years. These will clearly show to what extent *kumpta* cotton as usually known is a mixture of types of very different agricultural and commercial value.

"Dharwar No. 2" is one of these. When the fact was first recognized that there exist erect and bushy strains in *kumpta* cotton a number of plants showing the latter character (bushiness) were selected. The progeny of these plants were tested, and the best among them, which bred true, retained for trial and study.

This has been continued under the name "Dharwar No. 2." As with other bushy plants, this type bears, in general, a large number of limbs and axillary vegetative branches, which are more or less crowded about the central stalk. The type of plant is well shown on Plate IV (Fig. 2).

The results of cultivation of this type compared with the ordinary *kumpta* cotton are shown in the following two tables:—

1. *Yield of "kapas."*

Year	"Dharwar No. 2"	*Kumpta*	Percentage decrease of "Dharwar No. 2" from *Kumpta*
	Kapas yield per acre lb.	*Kapas* yield per acre lb.	
1915 ..	520	606	14·2
1916 ..	485	487	0·4
1917 ..	440	547	19·7
1918 ..	460	480	4·2
AVERAGE ..	476	530	9·6

2. *Ginning percentage.*

Year	"Dharwar No. 2"	*Kumpta*	Percentage increase of "Dharwar No. 2" from *Kumpta*
	Ginning percentage	Ginning percentage	
1915 ..	29·0	26·2	10·7
1916 ..	28·0	26·1	7·3
1917 ..	27·9	26·2	6·5
1918 ..	29·3	25·2	16·2
AVERAGE ..	28·5	25·9	10·1

These results indicate that "Dharwar No. 2" cannot compare with ordinary *kumpta* and even less with "Dharwar No. 1" in point of yield, but that the ginning percentage is high, equal in fact to that of "Dharwar No. 1." So far as yield is concerned, the *kapas* produced per acre is almost equal to that of *kumpta* in two years out of four, and it was suggested to me that the reason for its failure in the other years was the absence of the most favourable conditions of plant food and moisture. That this was not the case was proved by growing it under exceedingly favourable conditions at Gokak, when it showed the following yield and ginning percentage in comparison with "Dharwar No. 1."

Name of cotton	Yield of *kapas* per acre	Ginning percentage
	lb.	Per cent.
"Dharwar No. 1" ..	1,210	28·4
"Dharwar No. 2" ..	1,165	27·0

The staple of "Dharwar No. 2" was also inferior, even to ordinary *kumpta*. Valuations by Messrs. Tata Sons & Co. of the lint, per Bombay *candy* (784 lb.) in 1915 and 1916 were as follows :—

Year	"Dharwar No. 2" Value per *candy*	*Kumpta* Value per *candy*
	Rs.	Rs.
1915	315	335
1916	475	515

This selection from *kumpta* cotton appears, therefore, to have no future. It may possibly form the basis of a future crossing, and so the pure line stock is being maintained. Beyond that, its description is only valuable as showing the character of one of the inferior types included in the ordinary mixture known on the market as *kumpta* cotton.

"*Dharwar No. 3.*"

This selection from *kumpta* cotton has a long history dating back to year 1901. In that year a cross between two strains of *kumpta*, neither of them in

pure line cultivation, was made at Kirkee by Mr. Gammie. The resulting seed was sent in 1904 to Surat, where prolific plants were deliberately recrossed. This double cross between different strains of *kumpta* was grown at Surat till 1908, when it was finally transferred to Dharwar.

The work at that time was not conducted with real precision, and the produce was only further selected by mass selection on the basis of ginning percentage and better staple. The resulting seed, which was given the name of "*kumpta* cross," gave good promise of success from the first, at Dharwar. The staple was considered better than that of ordinary *kumpta*, and it was noted as being similar to *broach* cotton in style. In subsequent trials, the yield was, however, found to be lower than that of *kumpta* : while the ginning percentage and staple maintained more or less their superiority. By 1911, however, it was evident that the type was not pure, that it was rapidly losing its special characters of high-ginning percentage and staple, and that to obtain any satisfactory and reliable results individual selection would have to be carried on. The following figures which are interesting as showing how rapidly "deterioration" took place, indicate how the characters changed, when only mass selection was employed between 1908 and 1913 :—

Year	"KUMPTA CROSS"			"KUMPTA"		
	Yield of *kapas* per acre in lb.	Ginning per cent.	Value per *candy*	Yield of *kapas* per acre in lb.	Ginning per cent.	Value per *candy*
			Rs.			Rs.
1908	624	27·1	275	..	..	..
1909	431	25·4	300	..	..	..
1910	516	30·3	300	546	25·5	305
1911	438	26·1	315	360	23·8	290
1912	586	28·0	305	789	24·8	290
1913	456	24·6	235	503	23·3	235
AVERAGE	508	26·9	288	549	24·3	280

As it was obvious that the type had lost its special characters, individual selection was again begun in 1913, and the seed has been maintained in this manner since. The originally selected seed, self-fertilized, has been found to breed true, and has now formed a very useful type of *kumpta* cotton, which I

PLATE V.

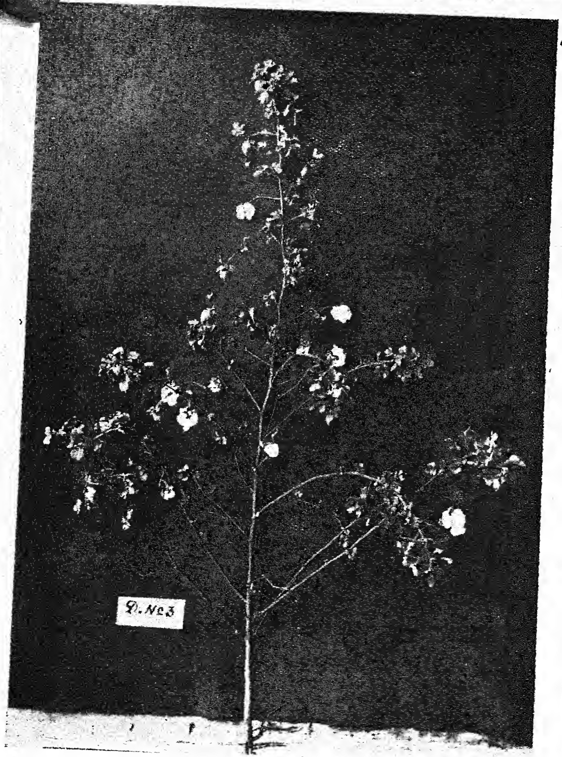


Fig. 3. Typical plant of "Dharwar No. 3" Cotton.

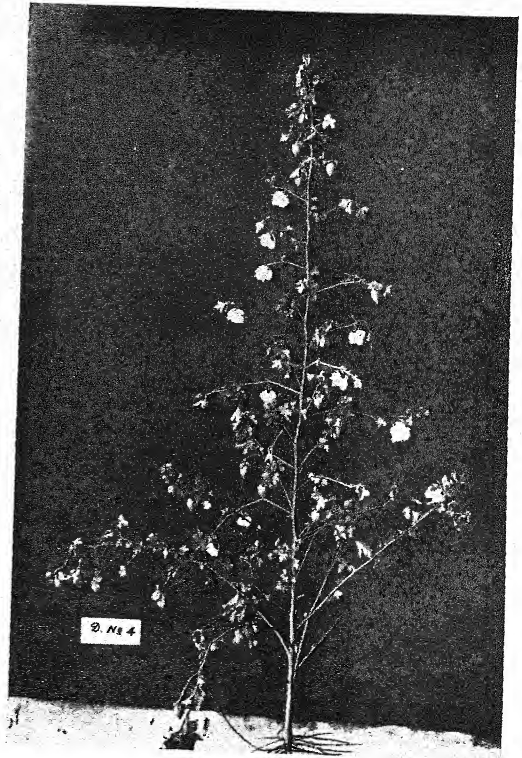


Fig. 4. Typical plant of "Dharwar No. 4" Cotton.

term "Dharwar No. 3" (Pl. V, fig. 1). The yield, ginning percentage and value are given below :—

Year	"DHARWAR NO. 3"				"KUMPTA"			
	Yield of *kapas* per acre	Ginning percentage	Yield of lint per acre	Value per *candy* (784 lb.)	Yield of *kapas* per acre	Ginning percentage	Yield of lint per acre	Value per *candy*
	lb.		lb.	Rs.	lb.		lb.	Rs.
1914 ..	532	33·0	175	245	542	27·0	146	230
1915 ..	528	31·2	165	350	564	26·1	147	335
1916 ..	540	30·2	163	540	626	24·3	152	530
1917 ..	420	33·2	139	900	440	24·7	108	900
1918 ..	432	33·1	143	..	480	25·2	120	..
AVERAGE ..	490	32·1	157	509	530	25·4	134	498

From these figures it will be seen that it has a considerably higher ginning percentage even than "Dharwar No. 1," that it has a market value at least as high or higher than ordinary *kumpta*, and that though its yield of *kapas* is low, its yield of lint per acre is generally higher than ordinary *kumpta*. Thus though the yield of *kapas* is less, the higher ginning outturn compensates for this loss of yield.

On the whole, however, it is not equal in value to "Dharwar No. 1" as the following average figures show :—

Name of cotton	*Kapas* per acre	Ginning percentage	Lint per acre	Average value per *candy* 1914 to 1917
	lb.		lb.	Rs.
"Dharwar No. 1" ..	563	28·5	160	524
"Dharwar No. 3" ..	490	32·1	157	509

Though these figures are not absolutely comparable, they show, I think, the position with regard to the two strains. If anything, the difference of yield should be more in favour of "Dharwar No. 1."

"Dharwar No. 3" is bushy in its habit of growth. It flowers late and this lateness is a disadvantage, especially in years when the rain during

October and November is heavy. The cotton, however, is an improvement on the ordinary *kumpta*, and there has grown up, in the transition tract of the Dharwar District, a considerable demand for its seed.

VII. Crosses of "kumpta" cotton with "ghogari" cotton.

Ghogari cotton is a variety of *Gossypium herbaceum* well recognized by the trade and by the cultivators, which originated so far as we know in the north of the Broach District in Gujarat. It has a very high-ginning percentage, often 40 per cent. or over, and this is its sole advantage. Its staple is short and rough, its yield is certainly not higher than that of other varieties of *herbaceum* cotton, and it has no special virtue of vigour or healthiness. The very large ginning percentage is its only advantage, but if this quality can be combined by crossing with *kumpta* cotton, without causing deterioration of the latter in other directions, a considerably better type will have been produced than any at present existing.

This was the principle on which my predecessors in cotton-breeding work based their crosses of *kumpta* with *ghogari* originally made at Dharwar in 1905. The care bestowed on keeping them pure later on was such that the value of the crosses was almost lost. In the first generation all good plants were picked collectively, but from the second generation unit selections were made for yield, for high-ginning, and for good staple.

For long, these selections were unsatisfactory as they continued to split, but finally two strains with fixed characters which, when self fertilized, breed true were obtained, one in the year 1913 and the other in 1914. These have been called respectively "Dharwar No. 4" and "Dharwar No. 5." These strains have the following characters :—

1. "Dharwar No. 4" is an intermediate type between the erect plant and a truly bushy one (Pl. V, fig. 2). It, however, produces no axillary vegetative branches. It flowers early like the *kumpta* parent, yields well, and gins much better than ordinary *kumpta* cotton. The staple is, however, short.

2. "Dharwar No. 5" is bushy in habit of growth, and late in flowering. Its yield is consequently small, but its ginning percentage is high, and its staple is good. It is, in fact, a very promising cotton, and in our hands has proved more profitable than *kumpta*.

The yield per acre of *kapas*, and of lint, their ginning percentage, and the value per candy of the lint, as compared with that of ordinary *kumpta* cotton, is shown in the following tables :—

1. *Yield of "kapas" per acre.*

Year	"Dharwar No. 4"	"Dharwar No. 5"	*Kumpta*
	lb.	lb.	lb.
1914	..	365	497
1915	666	395	420
1916	573	596	548
1917	448	392	440
1918	464	380	480
AVERAGE ..	538	425	475

2. *Yield of lint per acre.*

Year	"Dharwar No. 4"	"Dharwar No. 5"	*Kumpta*
1914	..	135	122
1915	213	142	100
1916	186	205	134
1917	147	147	115
1918	155	139	120
AVERAGE ..	175	153	118

3. *Ginning percentage.*

Year	"Dharwar No. 4"	"Dharwar No. 5"	*Kumpta*
1914	..	37·0	24·7
1915	32·1	36·2	24·0
1916	32·6	34·9	24·5
1917	33·0	37·5	26·2
1918	33·6	36·7	25·2
AVERAGE ..	32·8	36·4	24·9

4. *Value per* candy *(784 lb.) (Compared with the market price of* kumpta *cotton at the time).*

Year	"Dharwar No. 4"	"Dharwar No. 5"	*Kumpta*
	Rs.	Rs.	Rs.
1915	300	340	335
1916	480	520	515
1917	870	965	900
1918	635	645	625

From these figures it will be seen that "Dharwar No. 4" yields the largest yield per acre of *lint*, but the staple is undesirable, and hence the strain is one which in its present form it would not be wise to introduce. "Dharwar No. 5" yields less *kapas* per acre than ordinary *kumpta*, but its higher ginning percentage, a percentage in fact altogether unprecedented in a *kumpta* cotton, gives it a great advantage in the matter of lint. As its staple is also good, this strain seems to have advantage which may lead to its general usefulness in some parts of the *kumpta* area. For general introduction and use I prefer the selection known as "Dharwar No. 1," but "Dharwar No. 5" may surpass it as a commercial strain in certain cases, and in any case it will form an excellent basis for crossing with a high quality, high-yielding type, which suffers from having a low ginning percentage.

Each of the five strains of cotton produced by selection from *kumpta* ("Dharwar Nos. 1, 2 and 3") or by selection out of a *kumpta-ghogari* cross ("Dharwar Nos. 4 and 5") possess certain special characters (Plates VI and VII), which may now be tabulated side by side. In determining these figures, however, it may be stated that they have been obtained from the cottons growing on similar soil, side by side, at Dharwar. All grew vigorously there. The special characters of each of these strains are as follows :—

Dharwar No. 1. An erect and early type, suited for the whole of the *kumpta* tract. Staple better than ordinary *kumpta*.

Dharwar No. 2. A bushy type. Staple not desirable.

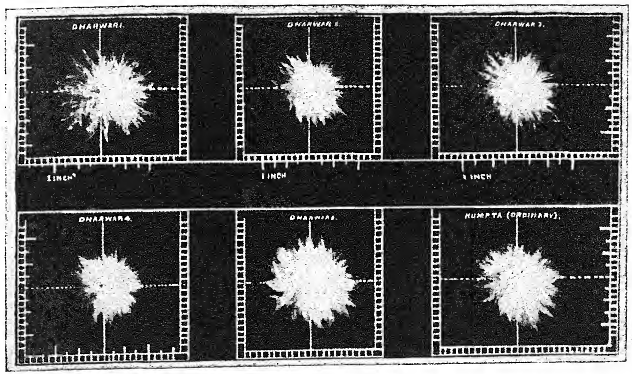
Dharwar No. 3. A bushy type, which has proved itself suitable for the transition tract. Staple better than ordinary *kumpta*.

Dharwar No. 4. A semi-erect and early type. Staple short.

Dharwar No. 5. A bushy and late type, but with very high-ginning percentage and good staple.

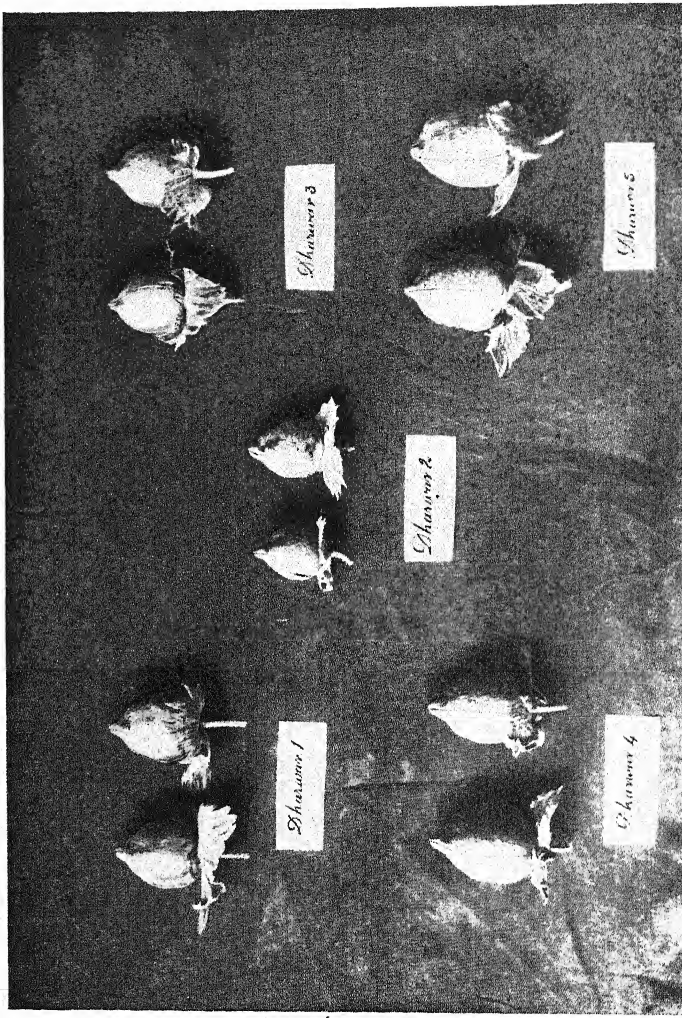
The average characters of each type in a series of years of cultivation are as follows. (The standard of comparison in the last two columns is *kumpta* cotton at Rs. 500 per *candy*) :—

Name of cotton	Yield of *kapas* per acre	Ginning percentage	Yield of lint per acre	Value per *candy*	Value of lint per acre
	lb.	Per cent.	lb.	Rs.	Rs.
Ordinary *kumpta* ..	467	25·5	119	500	75
"Dharwar No. 1" ..	563	28·5	160	526	107
"Dharwar No. 2" ..	476	28·5	135	349	60
"Dharwar No. 3" ..	450	32·1	157	511	102
"Dharwar No. 4" ..	538	32·8	175	470	105
"Dharwar No. 5" ..	425	36·4	153	520	101



Staples of "Dharwar Nos. 1, 2, 3, 4, and 5" and of ordinary *Kumpta*.

PLATE VII.



Bolls of "Dharwar Nos. 1, 2, 3, 4, and 5" Cottons.

It is obvious, from all these results and from the descriptions of the types which have been isolated from *kumpta* cotton, that we have in this cotton as it is usually grown, a mixture of a considerable number of strains differing in character of plant, in yield, in the ginning percentage of the *kapas* produced, and in the quality of the cotton lint. It is clear too that some at least of these strains breed true, and that, hence, it is possible by simple isolation of existing strains to get types which are better adapted to the special requirements of the cultivators and the trade than the mixture at present existing. It is clear, furthermore, that the qualities of earliness, yield, ginning percentage and staple are really in no way opposed to one another, and that there is no essential reason why an early cotton, with high yield, high ginning percentage, and good staple should not exist. These qualities are most nearly combined, so far as we have gone at present, in the cotton described as "Dharwar No. 1." But the existence of pure line strains of a cotton having all the characters of *kumpta* cotton, including long staple, but with a ginning percentage in pure line cultivation of over 36 per cent. by isolation from a simple cross with *ghogari* cotton, would lead to the belief that it will be possible to go much further and combine in one strain this ginning percentage with the other desirable qualities occurring in "Dharwar No. 1." This will be the object of the next stage of the work on *kumpta* cotton.

APPENDIX.

The supposed deterioration of types of cottons in cultivation.

During the course of the work described in the foregoing paper, the question frequently arose as to whether a type of cotton will deteriorate when grown in conditions which are not those in which it is normally found. The specific case was that of the successful attempt made some fifteen years ago to introduce *broach* cotton cultivation into the *kumpta* tract. That cultivation has been very successful in a limited area. The principal advantage of the *broach* type has been, however, the greater ginning percentage of the *kapas* combined with a staple equal to *kumpta*, and a lint very much better in colour and general appearance. It has been found, however, that unless fresh seed is constantly introduced from Gujarat, the cotton grown rapidly loses its advantages. The ginning percentage declines, the colour is lost. This has been ascribed to deterioration of the cotton owing to its being grown under conditions to which it is not accustomed. It may, however, equally well be due to cross fertilization with the local cotton. It is obvious that an examination of this case might give results of wider interest in studying the general question of deterioration.

The actual change in the ginning percentage of *broach* cotton *kapas* on growing at Dharwar is shown in the following table. Fresh seed was obtained every year, but at the same time the Dharwar-grown seed was also sown. Thus we can give the ginning percentage of seed which has been grown at Dharwar for almost any number of generations up to thirteen. The results are quoted for three years, 1914, 1915 and 1916:—

Generation	Ginning percentage during		
	1914	1915	1916
1st ..	32·7	32·1	33·5
2nd ..	32·7	32·5	32·4
3rd ..	32·4	34·1	32·0
4th ..	32·6	33·5	32·1
5th ..	28·0	32·9	30·6
6th ..	28·7	27·0	30·0
7th ..	29·1	28·1	27·7
8th ..	28·0	28·6	28·4
9th ..	..	27·5	28·2
10th ..	29·2	..	28·2
11th ..	29·2	28·4	..
12th ..	..	28·4	..
13th ..	..	..	28·7

From these figures it will be seen that the fall in ginning percentage is gradual to a definite limit, which is a little higher than that of the local *kumpta* cotton. The biggest drop, however, takes place in the fifth or sixth generation.

If this deterioration is due to crossing, then if the cotton can be self-fertilized, it ought not to take place. A series of generations starting from 1913 were, therefore, self-fertilized, and the effect on the ginning percentage of the following generations determined.

The method adopted was as follows: A number of plants were taken at random in each crop, and all the flowers of these plants were self-fertilized. The selfing was done by putting small iron rings on the flower buds so as to completely prevent the opening of the petals. The seed thus produced by self-fertilization was taken for the next sowing, and was hand-dibbled on an area of about one-twentieth of an acre. This supplies sufficient seed for trial on a field scale.

The result of applying this method to the *broach* cotton for a number of generations, starting from seed imported in the several years since 1913, is shown in the following table. The critical measurements were made in the three successive years 1916, 1917, and 1918.

Generation	Ginning Percentage during		
	1916	1917	1918
1st ..	33·6	36·1	37·2
2nd ..	32·5	34·0	36·7
3rd ..	34·1	34·0	35·4
4th ..	34·1	35·0	34·9
5th ..	..	34·5	36·1
6th ..	..	..	36·4

The percentages vary, but no fall in ginning percentage is indicated in the older generations. And it would seem to dispose completely of the idea that the continued growing of *broach* cotton in a tract like the Dharwar District to which it is unaccustomed is itself a cause of deterioration in the matter of ginning percentage. It is perhaps not entirely due to cross-fertilization, though the fact that cross-fertilization takes place in cotton is now established beyond all doubt. All the Indian varieties cross easily and the amount of natural crossing is considerable (up to six per cent.), when various varieties are grown in adjoining plots. The deterioration in large scale cultivation may not be entirely due, however, to this cause. There is also the question

of mixing seed in gins and elsewhere, and the persistence of self-sown plants in fields where cotton is continuously grown. But the evidence is very strong that we have not to fear a serious alteration in essential characters simply because of removal to different conditions like those of Dharwar, in the case of *broach* cotton.

BIBLIOGRAPHY OF "KUMPTA" COTTON.

Drury, H. Useful plants of India, London, 1873, page 233.

Walton, W. Cotton in Belgaum and Kaladgi Districts, Bombay, 1880.

Watt, G. Dictionary of Economic Products of India, Vol. IV, page 59, Calcutta, 1893.

Watt, G. Wild and Cultivated Cotton Plants of the World, London, 1908.

Middleton, J. Agricultural Ledger No. 8, Calcutta, 1895.

Gammie, G. Indian Cottons, Calcutta, 1905.

Gammie, G. The Indian Cottons, Mem. Dep. Agric., India (Bot. Ser.), Vol. II, No. 2 (1907).

Report of the Indian Cotton Committee, 1919, Calcutta, pages 117 and 123.